EAST WATERWAY OPERABLE UNIT
SUPPLEMENTAL REMEDIAL INVESTIGATION/ FEASIBILITY STUDY
QUALITY ASSURANCE PROJECT PLAN
FISH AND SHELLFISH TISSUE COLLECTION AND CHEMICAL ANALYSIS

For submittal to:

The US Environmental Protection Agency
Region 10
Seattle, WA

December 2008

Prepared by:

Wind Ward environmental LLC
200 West Mercer Street • Suite 401
Seattle, Washington • 98119

EAST WATERWAY Fish and Shellfish Tissue Collection and Chemical Analysis
FINAL QUALITY ASSURANCE PROJECT PLAN

APPROVALS

Windward Project Manager	Susan M'Gladdery Name	1/6/09 Date
Windward QA/QC Manager	[signature] Name	1/6/09 Date
EPA Project Manager	[signature] Name	1/22/09 Date
EPA QA Officer	[signature] Name	02/09/09 Date

Distribution List

This list identifies all individuals who will receive a copy of the approved quality assurance project plan, either in hard copy or electronic format, as well as any subsequent revisions.

- Ravi Sanga, EPA Project Manager
- Susan McGroddy, Windward Project Manager
- Matt Luxon, Windward Task Manager
- Thai Do, Windward Field Coordinator
- Ginna Grepo-Grove, EPA QA/QC Manager
- Marina Mitchell, Windward QA/QC Manager

Chemistry Project Managers:

- Sue Dunnihoo (Analytical Resources, Inc.)
- Amanda Fawley (Brooks Rand Labs LLC)
- Tamara Morgan (Analytical Perspectives)
- Greg Salata (Columbia Analytical Services, Inc.)

East Waterway Group:

- Doug Hotchkiss, Port of Seattle
- Debra Williston, King County
- Jeff Stern, King County
- Peter Rude, City of Seattle

Table of Contents

Tables

Figures

Maps

Acronyms

ACRONYM	Definition
%RSD	percent relative standard deviation
ANSETS	Analytical Services Tracking System
ARI	Analytical Resources, Inc.
CAS	Columbia Analytical Services, Inc.
BHRAA	borohydride reduction atomic absorption
Brooks Rand	Brooks Rand Labs LLC
COI	chemical of interest
CV	coefficient of variation
CVAA	cold vapor atomic absorption
DCM	dichloromethane
DGPS	differential global positioning system
DQI	data quality indicator
DQO	data quality objective
EPA	US Environmental Protection Agency
ERA	ecological risk assessment
EW	East Waterway
EWG	East Waterway Group
FC	field coordinator
GC/ECD	gas chromatography/electron capture detector
GC/FPD	gas chromatography/flame photometric detection
GC/MS	gas chromatography/mass spectrometry
GC/MS/MS	gas chromatography/mass spectrometry/mass spectrometry
GFAAS	graphite furnace atomic absorption spectrophotometry
CFR	Code of Federal Regulations
GPS	global positioning system
HAZWOPER	Hazardous Waste Operations and Emergency Response
HHRA	human health risk assessment
HRGC/HRMS	high resolution gas chromatography/high resolution mass spectrometry
HG/AFS	hydride generation/atomic fluorescence spectrometry
HSP	health and safety plan
ICP/AES	inductively couple/plasma atomic emission spectrometry

ACRONYM	Definition
ICP/MS	inductively coupled/plasma mass spectrometry
ID	identification
LCS	laboratory control sample
LDW	Lower Duwamish Waterway
MDL	method detection limit
MS	matrix spike
MSA	method of standard additions
MSD	matrix spike duplicate
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PM	project manager
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RL	reporting limit
RPD	relative percent difference
R/V	research vessel
SIM	selective ion monitoring
SOP	standard operating procedure
SRM	standard reference material
SVOC	semi-volatile organic compound
TM	task manager
UCL	upper concentration limit
USFWS	US Fish and Wildlife Service
WDFW	Washington State Department of Fish and Wildlife
Windward	Windward Environmental LLC

1 Introduction

This quality assurance project plan (QAPP) describes the sampling design and quality assurance (QA) objectives for collecting and analyzing fish, crab, shrimp, and mussel tissue in the East Waterway (EW). Details about project organization and management, field data collection methods, sample handling, laboratory analytical protocol, and data management and documentation are also provided. This QAPP was prepared in accordance with guidance for preparing QAPPs from the US Environmental Protection Agency (EPA) (2002).

Data from these studies will be used to support the ecological (ERA) and human health (HHRA) risk assessments for the Supplemental Remedial Investigation (SRI) and Feasibility Study (FS) for the EW.

- Section 2 – project management
- Section 3 – data generation and acquisition
- Section 4 – assessment and oversight
- Section 5 – data validation and usability
- Section 6 – references

Appendix A is a health and safety plan (HSP) designed to protect onsite personnel from physical, chemical, and other hazards posed by the field sampling effort. Field collection forms are included as Appendix B. Data management procedures are included as Appendix C. Risk-based analytical concentration goals are presented in Appendix D.

2 Project Management

This section describes the overall management structure of the project, identifies key personnel, and describes their responsibilities, including field coordination, quality assurance and quality control (QA/QC), laboratory management, and data management. The East Waterway Group (EWG) and the US Environmental Protection Agency (EPA) will be involved in all aspects of this project, including discussion, review, and approval of the QAPP, and interpretation of the results of the investigation.

2.1 Project Organization and Team Member Responsibilities

This sampling effort will be performed by Windward Environmental LLC (Windward) for the EWG. The overall project organization and the individuals responsible for the various tasks required for tissue sample collection and analysis are presented in

Figure 2-1. Responsibilities of project team members, as well as laboratory project managers (PMs), are described in the following subsections.

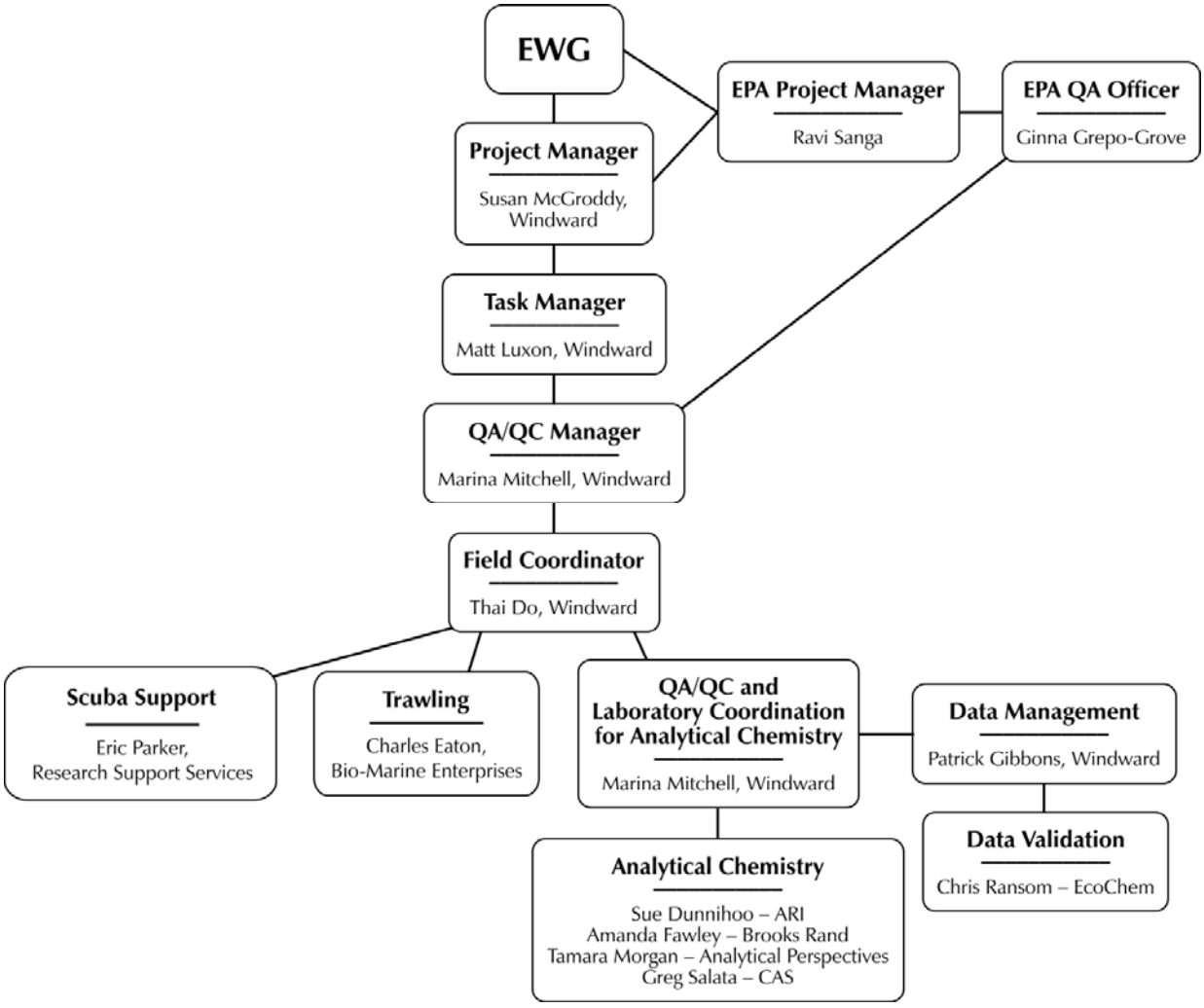


Figure 2-1. Project organization and team responsibilities

2.1.1 Project management

EPA will be represented by its PM, Ravi Sanga. Mr. Sanga can be reached as follows:

Mr. Ravi Sanga
US Environmental Protection Agency, Region 10
1200 Sixth Avenue, Suite 900
ECL-111
Seattle, WA 98101-3140
Telephone: 206.553.4092
Facsimile: 206.553.0124
E-mail: Sanga.Ravi@epamail.epa.gov

Susan McGroddy will serve as the Windward PM and will be responsible for overall project coordination and providing oversight on planning and coordination, work plans, all project deliverables, and performance of the administrative tasks needed to ensure timely and successful completion of the project. She will also be responsible for coordinating with EWG and EPA on schedule, deliverables, and other administrative details. Dr. McGroddy can be reached as follows:

Dr. Susan McGroddy
Windward Environmental LLC
200 W Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.577.1292
Facsimile: 206.217.0089
E-mail: susanm@windwardenv.com

Matt Luxon will serve as the Windward task manager (TM). The TM is responsible for project planning and coordination, production of work plans, production of project deliverables, and performance of the administrative tasks needed to ensure timely and successful completion of the project. The TM is responsible for communicating with the Windward PM on progress of project tasks and any deviations from the QAPP. Significant deviations from the QAPP will be further reported to EWG and EPA. Mr. Luxon can be reached as follows:

Mr. Matt Luxon
Windward Environmental LLC
200 W Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.577.1293
Facsimile: 206.217.0089
Email: mattl@windwardenv.com

2.1.2 Field coordination

Thai Do will serve as the Windward field coordinator (FC). The FC is responsible for managing the field sampling activities and general field and QA/QC oversight. He will ensure that appropriate protocols for sample collection, preservation, and holding times are observed and will oversee delivery of environmental samples to the designated laboratories for chemical analysis. Deviations from this QAPP will be reported to the TM and PM for consultation. Significant deviations from the QAPP will be further reported to representatives of EWG and EPA. Mr. Do can be reached as follows:

Mr. Thai Do
Windward Environmental LLC
200 W Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5407
Facsimile: 206.217.0089
Email: thaid@windwardenv.com

Charles Eaton will serve as the trawl boat captain. The trawl boat captain is responsible for operating the trawl boat and for decisions related to the operation of the trawl. The trawl boat captain will work in close coordination with the FC to ensure that samples are collected consistent with the methods and procedures presented in this QAPP. Mr. Eaton can be reached as follows:

Mr. Charles Eaton
Bio-Marine Enterprises
(b) (6)
Seattle, WA 98109
Telephone: 206.282.4945
Mobile: (b) (6)
Email: (b) (6)

2.1.3 Quality assurance/quality control

Marina Mitchell of Windward will oversee QA/QC for the project. As the QA/QC manager, she will oversee coordination of the field sampling and laboratory programs and supervise data validation and project QA coordination, including coordination with the EPA QA officer, Ginna Grepo-Grove.

Ms. Mitchell can be reached as follows:

Ms. Marina Mitchell
Windward Environmental LLC
200 W Mercer Street, Suite 401
Seattle, WA 98119

Telephone: 206.812.5424
Facsimile: 206.217.0089
Email: marinam@windwardenv.com

Ms. Grepo-Grove can be reached as follows:

Ms. Ginna Grepo-Grove
US Environmental Protection Agency, Region 10
1200 Sixth Avenue, Suite 900 (OEA-095)
Seattle, WA 98101
Telephone: 206.553.1632
Email: grepo-grove.gina@epa.gov

EcoChem Inc., will provide independent third-party review and validation of analytical chemistry data. Chris Ransom will act as the data validation PM and can be reached as follows:

Ms. Chris Ransom
EcoChem Inc.
Dexter Horton Building
710 Second Avenue, Suite 600
Seattle WA 98104
Telephone: 206.233.9332
Email: cransom@ecochem.net

2.1.4 Laboratory project management

Marina Mitchell of Windward will serve as the laboratory coordinator for the analytical chemistry laboratories (see contact information in Section 2.1.4). Analytical Resources, Inc. (ARI), Analytical Perspectives, Columbia Analytical Services, Inc. (CAS), and Brooks Rand Labs LLC (Brooks Rand) will perform chemical analyses. Sue Dunnihoo will serve as the laboratory PM for ARI, Amanda Fawley will serve as the laboratory PM for Brooks Rand, Tamara Morgan will serve as the laboratory manager for Analytical Perspectives, and Greg Salata (or other qualified personnel) will serve as the laboratory PM for CAS. The laboratory PMs can be reached as follows:

Ms. Susan Dunnihoo
Analytical Resources, Inc.
4611 S 134th Place, Suite 100
Tukwila, WA 98168
Telephone: 206.695.6207
Email: sue@arilabs.com

Ms. Amanda Fawley
Brooks Rand Labs LLC
3958 Sixth Avenue NW

Seattle, WA 98107
Telephone: 206.632.6206
Facsimile: 206.632.6017
Email: amanda@brooksrand.com

Ms. Tamara Morgan
Analytical Perspectives
2714 Exchange Drive
Wilmington, NC 28405
Telephone: 910.794.1613
Facsimile: 910.794.3919
Email: tmorgan@ultratrace.com

Mr. Greg Salata
Columbia Analytical Services, Inc.
1317 S 13th Avenue
Kelso, WA 98626
Telephone: 360.577.7222
Facsimile: 360. 636.1068
Email: gsalata@kelso.caslab.com

The laboratories will do the following:

- Adhere to the methods outlined in this QAPP, including those methods referenced for each procedure
- Adhere to documentation, custody, and sample logbook procedures
- Implement QA/QC procedures defined in this QAPP
- Meet all reporting requirements
- Deliver electronic data files as specified in this QAPP
- Meet turnaround times for deliverables as described in this QAPP
- Allow EPA and the QA/QC manager, or a representative, to perform laboratory and data audits

2.1.5 Data management

Mr. Patrick Gibbons will oversee data management to ensure that analytical data are incorporated into the EW database with appropriate qualifiers following acceptance of the data validation. QA/QC of the database entries will ensure accuracy for use in the ERA and HHRA.

2.2 PROBLEM DEFINITION/BACKGROUND

The Duwamish River discharges to Elliott Bay (Map 2-1) in Seattle, Washington. The river forms two branches approximately 1 mile from its mouth. The EW is the eastern branch of the Duwamish River along the east side of Harbor Island. This site has been designated as an operable unit of the Harbor Island Superfund site.

Windward Environmental LLC (Windward) is conducting Ecological and Human Health Risk Assessments of the EW. The objective of this sampling effort is to further characterize the EW environment and collect data that will be used to determine risks to the organisms living in or using the waterway and to humans who consume seafood from the waterway. Cleanup of sediment contamination will occur in the EW as part of the Superfund process to address risks to human health and ecological receptors.

The primary objectives for the tissue data to be collected under the fish, crab, and mussel QAPP are to:

- Characterize chemical exposure for selected fish and crab receptors of concern (ROCs) through all exposure routes via a tissue residue exposure analysis.
- Characterize chemical exposure to fish, wildlife (birds and mammals), and humans through the foodchain via dietary exposure analyses.

2.3 PROJECT/TASK DESCRIPTION AND SCHEDULE

This section provides an overview of the sampling and analysis activities and schedule for the four studies designed to address the objectives outlined in Section 2.2. Detailed sampling designs are presented in Section 3.1. All samples will be collected during August and September, 2008. Sampling will be coordinated with the Muckleshoot tribe to ensure that trawling does not conflict with Muckleshoot tribal salmon fishing, which also occurs during this time period. Chemical analysis of the samples described in Section 3.4 will be completed approximately 10 weeks[1] after compositing and homogenization has been completed. Data validation will be completed approximately 3 weeks after receipt of the chemistry data. A draft data report will be completed approximately 45 days following receipt of the validated data.

2.3.1 Trawl sampling

English sole (*Parophrys vetulus*), shiner surfperch (*Cymatogaster aggregata*), and cancrid crabs (*Cancer spp*) will be collected using high-rise otter trawl. Trawling will take place near the first week in September 2008 to coincide with time period when Lower Duwamish Waterway (LDW) fish and crab samples have historically been collected. Trawling will take place the first week of September and will be coordinated with the

[1] Samples archived for dioxin and furan and PCB congener analysis will be analyzed following review of the preliminary PCB Aroclor results.

Muckleshoot tribe to ensure that trawling does not conflict with Muckleshoot tribal salmon fishing, which also occurs during this time period. Samples will be collected throughout all accessible areas of the EW.

2.3.2 Trap sampling

Cancrid crabs and coonstripe shrimp (*Pandalus danae*) will be collected using traps. Crab traps and shrimp traps will be deployed the week of August 25th. Sampling during this period will avoid the molten period which is generally late winter-early spring. Samples will be collected throughout the EW focusing on areas inaccessible to the trawl such as under bridges, on rip-rap, and beneath pier aprons.

2.3.3 SCUBA sampling

Brown rockfish (*Sebastes auriculatus*) will be collected by SCUBA divers; collection will take place in August 2008 so that SCUBA sampling precedes trawl sampling. If insufficient numbers of brown rockfish are collected during SCUBA sampling, an alternative piscivore, Pacific staghorn sculpin (*Leptocottus armatus*), will be targeted for collection during trawling. Samples will be collected throughout the EW from suitable rockfish habitat such rip-rap, debris, and pilings.

2.3.4 Hand sampling

Blue mussels (*Mytilus edulis*) will be collected by hand (from a boat) from pilings in the EW in August 2008. Samples will be collected throughout the EW from as near the sediment surface as is feasible.

2.4 DATA QUALITY OBJECTIVES AND CRITERIA

The overall data quality objective (DQO) for this project is to develop and implement procedures that will ensure the collection of representative data of known, acceptable, and defensible quality. Parameters used to assess data quality are precision, accuracy, representativeness, comparability, completeness, and sensitivity. These parameters are discussed, and specific data quality indicators (DQIs) for tissue and sediment laboratory analysis are presented in Section 3.5.

2.4 SPECIAL TRAINING/CERTIFICATION

The Superfund Amendments and Reauthorization Act of 1986 requires the Secretary of Labor to issue regulations through the Occupational Safety and Health Administration (OSHA) to provide health and safety standards and guidelines for workers engaged in hazardous waste operations. Federal regulation 29CFR1910.120 requires training to provide employees with the knowledge and skills necessary to enable them to perform their jobs safely and with minimum risk to their personal health. All sampling personnel will have completed the 40-hour Hazardous Waste

Operations and Emergency Response (HAZWOPER) training course and 8-hour refresher courses, as necessary, to meet the OSHA regulations.

Other relevant regulations involve collection permits. Three fish sampling permits are needed for the sampling described in this QAPP (Table 2-1). Permits are required by the Washington State Department of Fish and Wildlife (WDFW) for any scientific collection of organisms and by the federal service agencies (National Marine Fisheries Service and US Fish and Wildlife Service) for lethal and incidental take of threatened fish species (i.e., Chinook salmon, steelhead salmon, and bull trout). Matt Luxon is the permit holder for all permits. The FC and the leader of each sampling team (i.e., trawl sampling, trap sampling, and beach seine sampling) will be in possession of a copy of each permit, as required by the permits. Copies of permits are available upon request.

Table 2-1. Required Fish Sampling Permits

PERMIT	PERMIT NUMBER
USFWS incidental take permit for threatened and endangered species (bull trout); required even though this species is not targeted for collection because they may be caught incidentally in the sampling gear.	Threatened Species Permit TE088853-0
NMFS Endangered Species Act Section 10(a)(1)(A) research permit for threatened and endangered species (i.e., Chinook salmon and steelhead salmon); required even though this species is not targeted for collection because they may be caught incidentally in the sampling gear.	Scientific Research Permit 1605
WDFW scientific collection permit.	Scientific Collection Permit 08-188

NMFS – National Marine Fisheries Service
USFWS – US Fish and Wildlife Service
WDFW – Washington State Department of Fish and Wildlife

2.5 DOCUMENTATION AND RECORDS

This section describes the documentation and records needed for field activities and laboratory analyses, as well as the data reduction process and contents of the data report. .

2.5.1 Field observations

All field activities will be recorded in a field logbook maintained by the FC. The field logbook will include a description of all sampling activities associated with field sampling activities, sampling personnel, and weather conditions, plus a record of all modifications to the procedures and plans identified in this QAPP and the HSP (Appendix A). The field logbook will consist of bound, numbered pages. All entries will be made in indelible ink. The field logbook is intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during the sampling period.

The following field data collection sheets, included as Appendix B, will also be used to record pertinent information during sample collection:

- Protocol Modification Form
- Target Species Tally Form
- Non-Target Species Tally Form
- Mussel Collection Form
- Surface Sediment Collection Form
- Specimen label
- Composite Sample Form

2.5.2 Laboratory records

The chemistry laboratories will be responsible for internal checks on sample handling and analytical data reporting and will correct errors identified during the QA review. The laboratory data package will be submitted electronically and will include the following:

- **Project narrative**: This summary, in the form of a cover letter, will present any problems encountered during any aspect of analysis. The summary will include, but not be limited to, a discussion of QC, sample shipment, sample storage, and analytical difficulties. Any problems encountered by the laboratory, and their resolutions, will be documented in the project narrative.
- **Records**: Legible copies of the chain-of-custody forms will be provided as part of the data package. This documentation will include the time of receipt and the condition of each sample received by the laboratory. Additional internal tracking of sample custody by the laboratory will also be documented.
- **Sample results**: The data package will summarize the results for each sample analyzed. The summary will include the following information, as applicable:
  - Field sample identification code and the corresponding laboratory identification code
  - Sample matrix
  - Date of sample extraction/digestion
  - Date and time of analysis
  - Weight and/or volume used for analysis
  - Final dilution volume or concentration factor for the sample
  - Identification of the instruments used for analysis
  - Method detection limits (MDLs) and reporting limits (RLs)

- All data qualifiers and their definitions

- **QA/QC summaries:** These summaries will contain the results of all QA/QC procedures. Each QA/QC sample analysis will be documented with the same information as that required for the sample results (see above). The laboratory will make no recovery or blank corrections. The required summaries are listed below.
  - The calibration data summary will contain the concentrations of the initial calibration and daily calibration standards and the date and time of analysis. The response factor, percent relative standard deviation (%RSD), relative percent differences (RPDs), and retention time for each analyte will be listed, as appropriate. Results for standards analyzed at the RL to indicate instrument sensitivity will also be reported.
  - The internal standard area summary will report the internal standard areas, as appropriate.
  - The method blank analysis summary will report the method blank analysis associated with each sample and the concentrations of all analytes identified in these blanks.
  - The surrogate spike recovery summary will report all surrogate spike recovery data for organic analyses. The names and concentrations of all compounds added, percent recoveries, and QC limits will be listed.
  - The matrix spike (MS) recovery summary will report the MS or MS duplicate (MSD) recovery data for analyses, as appropriate. The names and concentrations of all compounds added, percent recoveries, and QC limits will be included in the data package. The RPD for all MS/MSD analyses will be reported.
  - The laboratory replicate summary will report the RPD for all laboratory replicate analyses. The QC limits for each compound or analyte will be listed.
  - The standard reference material (SRM) analysis summary will report the results and recoveries of the SRM analyses and list the accuracy, as defined in Section 3.4.3, for each analyte, when available.
  - The laboratory control sample (LCS) analysis summary will report the results of the analyses of the LCS. The QC limits for each compound or analyte will be included in the data package.
  - The relative retention time summary will report the relative retention times for the primary and confirmational columns of each analyte detected in the samples, as appropriate.

- **Original data:** Legible copies of the original data generated by the laboratory will be provided, including the following:
  - Sample preparation, extraction/digestion, and cleanup logs
  - Instrument analysis logs for all instruments used on days of calibration and analysis
  - Chromatograms for all samples, blanks, calibration standards, MS/MSD, laboratory replicate samples, LCS, and SRM samples for all gas chromatography analyses
  - Reconstructed ion chromatograms of target chemicals detected in the field samples and method blanks for all gas chromatography/mass spectrometry (GC/MS) analyses
  - Enhanced and unenhanced spectra of target chemicals detected in field samples and method blanks, with associated best-match spectra and background-subtracted spectra, for all GC/MS analyses
  - Quantitation reports for each instrument used, including reports for all samples, blanks, calibrations, MS/MSD, laboratory replicates, LCS, and SRMs

The contract laboratories for this project will submit data electronically, in EarthSoft EQuIS® standard four-file or EZ_EDD format. Guidelines for electronic data deliverables for chemical data is provided on the EarthSoft website, http://www.earthsoft.com/en/index.html, and additional information will be communicated to the laboratories by the project QA/QC coordinator or data manager. All electronic data submittals must be tab-delimited text files with all results, MDLs, and RLs reported to the appropriate number of significant figures. If laboratory replicate analyses are conducted on a single submitted field sample, the laboratory sample identifier must distinguish among the replicate analyses.

2.5.3 Data reduction

Data reduction is the process by which original data (analytical measurements) are converted or reduced to a specified format or unit to facilitate data analysis. Data reduction requires that all aspects of sample preparation that could affect the test result, such as sample volume analyzed or dilutions required, be taken into account in the final result. It is the laboratory analyst's responsibility to reduce the data, which are subjected to further review by the laboratory data review specialists, laboratory PM, project QA/QC coordinator, project PM, and independent data reviewers. The data will be generated in a form amenable to review and evaluation. Data reduction may be performed manually or electronically. If performed electronically, all software used must be demonstrated to be true and free from unacceptable error.

2.5.4 Data report

A data report will be prepared to document all activities associated with the collection, handling, and analysis of samples. At a minimum, the following will be included in the data report:

- Summary of all field activities, including descriptions of any deviations from the approved QAPP
- Summary spreadsheet that contains information from field forms
- Sampling locations reported in latitude and longitude to the nearest one-tenth of a second and in northing and easting to the nearest foot.
- Trawl start and end points will be recorded using a Trimble NT300D differential global positioning system (DGPS) with 1-2 m accuracy. When the trawl is deployed on the bottom, GPS and clock readings will be taken to mark the starting point of the trawl. Final GPS and clock readings will be made when net retrieval begins.
- Summary of the QA/QC review of the analytical data
- Results from the analysis of field samples included as summary tables in the main body of the report, data forms submitted by the laboratories, and cross-tab tables produced from Windward's database

A Microsoft Access database containing tissue chemistry data will be submitted to EPA. The structure of the database will be similar in structure to that provided to EPA for the LDW project.Once the data report has been approved by EPA, a database export will be created from Windward's database. The data will be exported in a format compatible with the Washington State Department of Ecology's Environmental Information Management System, which consists of separate tables for events, locations, samples, and results.

3 Data Generation and Acquisition

This section describes the methods that will be used to collect, process, and analyze fish, crab, shrimp, and mussel tissue samples collected from the EW. Elements include species selected for sampling, sampling design; fish and crab sampling methods; sample handling and custody requirements; analytical chemistry methods; QA/QC; instrument and equipment testing, inspection, and maintenance; instrument calibration; supply inspection and acceptance; non-direct measurements; and data management.

3.1 SPECIES SELECTED FOR SAMPLING

The Draft Conceptual Site Model (CSM) and Data Gaps Analysis Report identify cancrid crabs, juvenile Chinook salmon,[2] English sole, and brown rockfish as ROCs for which EW tissue residue data are necessary for characterization of exposure (Anchor et al. 2008). Additional tissue residue data for bivalves and prey fish (including juvenile Chinook salmon and shiner surfperch or a suitable alternative) are identified as data gaps to model dietary exposure for fish, bird, and mammalian ROCs and for various human health seafood consumption scenarios (Anchor et al. 2008). The species to be collected under the fish, crab, shrimp, and mussel tissue QAPP are identified below with a brief discussion of the basis for their selection. The species are presented in Table 3-1 along with associated data uses.

[2] Juvenile Chinook salmon tissue residue data will be collected in 2009 under an addendum to the fish and crab QAPP to be provided in October 2008 because an additional NOAA permit is required for lethal take of juvenile Chinook salmon. Acquiring this permit will take approximately one year so sampling in 2008 is infeasible.

Table 3-1. Proposed species targeted for collection and associated data uses

TARGET SPECIES	SIZE (cm)	TISSUE TYPE	ROC CONSUMING OR REPRESENTED BY TARGET SPECIES	SIZE PREFERENCE OF PREY	ROC EXPOSURE AREA	DATA USE
Brown rockfish (*Sebastes auriculatus)*	≥ 20	whole body	brown rockfish	NA	localized areas	compare UCL to tissue TRV
			pigeon guillemot	<10 cm	site-wide	compare UCL to dietary TRV/human consumption of fish-shellfish scenario
			osprey	11-30 cm		
			river otter	7.6-41cm		
			harbor seal	4-28cm		
			humans	≥20 cm		
English sole (*Parophrys vetulus)*	≥ 20	whole body	English sole	NA	site-wide	compare UCL to tissue TRV
						compare UCL to dietary TRV/human consumption of fish-shellfish scenario
			pigeon guillemot	<10 cm	site-wide	
			osprey	11-30 cm		
			river otter	7.6-41cm		
			harbor seal	4-28cm		
			humans	≥20 cm		
		fillet	humans	≥20 cm		
Cancrid crab (Dungeness, red rock, slender)	≥ 9	edible meat and hepato-pancreas	Cancrid crab	NA	site-wide	compare UCL to tissue TRV
			brown rockfish (crabs are surrogate for shrimp prey)	NA		compare UCL to dietary TRV/human consumption of fish-shellfish scenario
			pigeon guillemot	<10 cm		
			river otter	7.6-41cm		
			humans	≥13 cm		
Shiner surfperch (*Cymatogaster aggregata)*	≥8	whole body	osprey	11-30 cm	site-wide	compare UCL to dietary TRV/human consumption of fish-shellfish scenario
			brown rockfish	<10 cm		
			pigeon guillemot	<10 cm		
			river otter	7.6-41cm		
			harbor seal	4-28cm		

TARGET SPECIES	SIZE (cm)	TISSUE TYPE	ROC CONSUMING OR REPRESENTED BY TARGET SPECIES	SIZE PREFERENCE OF PREY	ROC EXPOSURE AREA	DATA USE
			humans	≥8 cm		
Juvenile English sole (surrogate for shiner surfperch)	9-13	whole body	osprey	11-30 cm	site-wide	compare UCL to dietary TRV
			brown rockfish	small (<10 cm)		
			pigeon guillemot	small (<10 cm)		
			River otter	7.6-41cm		
			harbor seal	4-28cm		
Coonstripe shrimp (*Pandalus danae*) and Blue mussel (*Mytilus edulis*)	any size	whole body and soft tissue for shrimp and mussel, respectively				compare UCL to dietary TRV
						compare UCL to dietary TRV/human consumption of fish-shellfish scenario
			brown rockfish	<10 cm	localized areas	
			pigeon guillemot	<10 cm	site-wide	
			River otter	>2cm		
			humans	>2cm		

TRV – toxicity reference value
UCL – upper confidence limit on the mean
NA – not applicable

3.1.1 Brown rockfish

Brown rockfish were selected as an ROC to represent upper-trophic-level fish in the EW. Brown rockfish are long-lived demersal fish that feed on fish and larger invertebrates than do English sole, thus increasing their potential exposure to bioaccumulative and biomagnifying chemicals, such as mercury and polychlorinated biphenyls (PCBs). Upper-trophic-level fish may have higher body burdens of biomagnifying chemicals than do lower-trophic-level fish, such as English sole, that ingest primarily invertebrates. Because brown rockfish are long-lived compared to some other upper-trophic level fish in the EW, they can be exposed for longer periods and, thus, have a greater potential to bioaccumulate persistent chemicals such as PCBs and mercury over time.

Brown rockfish are noted to be relatively sedentary, with home ranges that range from 30 m^2 or less on artificial and high-relief reefs to 90 to 1,500 m^2 on low-relief reefs where bull kelp is present (Matthews 1990b). Their home range in the EW is uncertain because the availability of these habitats in the EW is uncertain. Based on reported habitat preferences (Love 1996; Matthews 1990b), brown rockfish in the EW are likely to be associated with pier structures, riprap, or other debris (e.g., old tires).

Brown rockfish reach maturity at three years and approximately 20 cm (DeLacey et al. 1964 as cited in Stein and Hassler 1989). Adult fish (≥20cm) are being targeted because they likely have accumulated higher concentrations of persistent chemicals during their lifetime than smaller fish so represent conservative estimates of contaminant burdens in EW brown rockfish. Fish >20 cm are likely targeted by human anglers, and represent conservative estimates of exposure for the piscivorous wildlife ROCs for which rockfish data will be used in exposure estimates (Table 3-1).

If insufficient brown rockfish are collected over 5 days of SCUBA sampling in August, brown rockfish (>200 mm), staghorn sculpin (>150 mm), and sandsole (>200 mm) will be collected opportunistically during trawl sampling and archived for potential chemical analysis.

3.1.2 English sole

English sole (*Pleuronectes vetulus*) were selected as an ROC to represent benthivorous and planktivorous fish in the EW. English sole live in close proximity to sediment and, thus, have a high potential for direct exposure to sediment-associated chemicals. In addition, English sole feed extensively on infaunal and epifaunal invertebrates and, thus, are exposed to sediment-associated chemicals through their diet. Based on trawl data, English sole are one of the most abundant fish in the EW (Windward 2006a).

English sole may exist in discrete populations with some site fidelity (Day 1976) which would allow them to accumulate contaminants from a more limited area; however, home ranges of English sole in the EW likely extend beyond the boundaries of the EW.

A few home range estimates have been developed for English sole using best professional judgment; these include a 9-km^2 home range, as reported in the Puget Sound Dredged Disposal Analysis (PSDDA) Report (PSDDA 1988), and a 2-km^2 home range based on a literature review (Stern et al. 2003).

Whole body total PCBs (sum of Aroclor) tissue concentrations in English sole collected from the LDW indicate spatially distinct contaminant uptake over the 5-mile long waterway. The mean total PCB concentrations in English sole from the most upstream segment of the waterway (RM 4.2 to 4.8) where significantly lower than those from the two most downstream segments of the waterway (RM 0.2-1.0, and RM 1.6 to 2.4) based on 2004 data. Based on 2005 data, total PCBs concentrations in English sole from RM 4.2 to 4.8 were significantly different from those from RM 1.6 to 2.4. Although the factors affecting the observed spatial differences in total PCBs tissue concentrations in English sole from the LDW are uncertain, these data suggest that English sole may have foraging areas less than the 5 mile long LDW and larger than the 0.8 mile long LDW exposure areas or the 1 ½ mile long East Waterway.

English sole reach sexual maturity at two to four years and approximately 20 to 30 cm (Harry 1959 as cited in Lassuy 1989). Fish (≥20cm) are being targeted because this size was targeted for the LDW ERA and HHRA. Additionally English sole in this size range have likely accumulated higher concentrations of persistent chemicals during their lifetime than smaller fish so represent conservative estimates of contaminant burdens in the EW English sole population. Fish ≥20 cm are likely targeted by human anglers, and represent conservative estimates of exposure for the piscivorous wildlife ROCs for which English sole data will be used in exposure estimates (Table 3-1).

3.1.3 Cancrid crabs

Cancrid crabs were selected as an ROC because they are ecologically and recreationally important, and an important resource to tribal harvesters. Additionally, crabs have a higher trophic level than do other benthic invertebrates. Although no individual is likely to be a long-term resident of the EW (adult crab often exhibit seasonal use of shallow habitats and select protected environments as juveniles), cancrid crab are anticipated to be present in the EW. Graceful crab (also known as slender crab) are typically the most abundant, but red rock and Dungeness crab have also been found in the EW.

Target species include (in order of preference) Dungeness crab, red rock crab, and slender crab.

Crabs greater than 9cm are being targeted for collection because there should be sufficient numbers of crab specimens at this size and above, and because this size was targeted for the LDW ERA and HHRA. Crabs in this size range have likely accumulated higher concentrations of persistent chemicals during their lifetime than smaller crabs so represent somewhat conservative estimates of contaminant burdens

in the EW crab population. Crabs ≥9 cm represent the lower end of crabs that are likely targeted by human anglers. The legal size limit for crabs is 13 and 16 cm for red rock and Dungeness crabs, respectively, however, smaller crabs may be consumed. This size range represents conservative estimates of exposure for the and wildlife ROCs for which crab data will be used in exposure estimates (Table 3-1).

3.1.4 Potential human market basket seafood species and wildlife prey species

In addition to brown rockfish, English sole, and cancrid crabs, which will be collected to represent exposure to themselves as ROCs via a tissue residue line of evidence and to represent exposure to higher trophic level ROCs via a dietary line of evidence, additional tissue data are needed to represent dietary exposure from smaller prey fish, bivalves, and potentially shrimp. Potential prey for higher trophic level consumers include shiner surfperch, juvenile English sole, coonstripe shrimp, and blue mussel. Advantages and disadvantages for use of each of these species are discussed below.

3.1.4.1 Shiner surfperch

Shiner surfperch were used as prey for ecological receptors and as part of the human health dietary market basket for the LDW risk assessments. This species was also indicated as a likely fish prey species in the Draft EW CSM and Data Gaps Analysis Report (Anchor et al. 2008).

Pros:

- Shiner surfperch are common in the EW.
- Data will be comparable to historical EW and LDW data.
- Conservative because they have a benthic diet and LDW data show fairly high tissue concentrations of PCBs.

Cons:

- Likely include exposures to areas outside the EW due to seasonal migrations.

Comparison of PCB homolog sediment and shiner surfperch tissue data collected from the four sampling areas of the LDW site indicated that despite seasonal migration, perch accumulated PCBs from sampling areas of approximately 1 mile within the LDW (Kissinger 2006). It should be noted that the entire EW is approximately 1.4 miles long which is similar in size to each of the sampling areas that were compared in the LDW, so it is uncertain whether shiner surfperch uptake of PCBs in the EW might relate to localized areas of the site.

Overall, shiner surfperch are an appropriate prey species and thus will be collected as representative prey fish. If insufficient shiner surfperch can be collected after 2 days of trawling, juvenile English sole should be collected as a surrogate species.

Shiner surfperch ≥ 8cm are being targeted because this size was targeted for the LDW ERA and HHRA. Shiner surfperch in this size range are likely adults; shiner surfperch grow rapidly and reach maturity within the first year (Bane and Robinson 1970). Shiner surfperch in this size range have likely accumulated higher concentrations of persistent lipophilic chemicals during their lifetime than smaller shiner surfperch, and so represent conservative estimates of contaminant burdens in the EW shiner surfperch population. Shiner surfperch ≥ 8 cm are likely a reasonable representation of those targeted by human anglers because larger shiner surfperch are uncommon. This size range likely represents a reasonable estimate of exposure for the piscivorous fish and wildlife ROCs for which shiner surfperch data will be used in exposure estimates (Table 3-1).

3.1.4.2 Juvenile English sole

A surrogate prey fish species is needed in the event that sufficient shiner surfperch cannot be collected. Juvenile English sole were the most abundant fish caught in the EW during trawling in 2005 (Windward 2006a). The following are pros and cons for use of this fish species as a surrogate prey species for the EW risk assessments:

Pros:

- Likely to be exposed within the EW for entire juvenile period.
- Abundant in 2005 EW trawls.

Cons:

- No historical LDW or EW tissue chemistry data.

Juvenile English sole are an appropriate prey species. They will only be collected if insufficient shiner surfperch can be collected after 2 days of trawling.

3.1.4.3 Coonstripe shrimp

Coonstripe shrimp are a benthic carnivore that can be used as another prey species in the EW risk assessments. The following are pros and cons for the use of this prey species:

Pros:

- An important prey species for brown rockfish.
- Realistic prey for pigeon guillemot.
- Realistic prey for human fish/shellfish exposure scenario.

Cons:

- May be difficult to obtain sufficient numbers for sampling. Only 60 were obtained in the LDW in the November 2004 quarterly survey, with much fewer in the other quarters (Windward 2006b).

Shrimp appear to be a potential prey species and will be collected opportunistically during trawling and trapping and archived for potential chemical analysis. Coonstripe shrimp of all sizes will be targeted. Shrimp data will be used to model exposure to humans and brown rockfish. These receptors likely consume the variety of shrimp sizes encountered in the EW.

3.1.4.4 Blue mussel

Blue mussel are a water column filter-feeding bivalve. The following are pros and cons for the use of this species:

Pros:

- Likely provide sufficient tissue for all chemical analyses.
- Realistic prey for human fish/shellfish exposure scenario.
- Allows comparison with clam data to evaluate differences in exposure pathways.

Cons:

- The connection with sediment exposure is less certain than for clams.

As described in Section 3.3.4, mussels will be collected opportunistically from as close to the sediment surface as feasible and archived for potential chemical analysis. Mussels of all sizes will be targeted. Mussel data will be used to model exposure to humans and river otters. These receptors likely consume the variety of mussel sizes encountered in the EW.

3.2 SAMPLING DESIGN

This section presents the sampling design including the compositing procedures, numbers of samples, the analyte list and associated methods, and the sampling plan.

The goal of the sampling design is to characterize average concentrations of EW chemical of interest (COI) tissue burdens of each target species throughout the EW. To this end, with the exception of rockfish, composite samples will be used in order to represent more individuals and thus a greater proportion of the population in samples. Compositing also allows for sufficient tissue mass to analyze for the full suite of chemicals of interest. Brown rockfish will be analyzed as individuals because they are expected to have localized exposure in different areas of the EW and not expected to be as abundant as other target fish species.

Factors that may affect the chemical tissue burdens of each target species include:

- Seasonal use of the EW, resulting in potential exposure to chemicals outside of the EW
- Habitat use within the EW

- Gender
- Age and size
- Developmental stage (e.g., juvenile versus adult), with resulting seasonal changes in reproductive development, lipid storage, and metabolism
- Episodic changes in bioavailability of contaminants (e.g., large sediment resuspension events such as dredging)

The foraging ranges of adult English sole and crabs are likely to be as large as or larger than the EW; therefore, specimens of a given species collected from anywhere within the EW are likely to have similar exposures. Thus, adult English sole and crab composite samples created by means of random sampling throughout the EW will provide an unbiased estimate of tissue concentrations in the populations that use the EW. Individual brown rockfish have home ranges of approximately 30 square meters (m^2) on artificial reefs (such as riprap) (Matthews 1990); therefore, rockfish are likely to be exposed to localized conditions within the EW, so samples will be of individual fish. Mussel and shrimp samples will be collected from throughout the EW and specimens from each collection location will be individually packaged and archived frozen.

Composite samples will be used to represent more individuals, thereby providing better estimates of mean tissue concentrations in the populations of each target species in the EW. Compositing also provides sufficient tissue mass for an analysis of the full suite of COIs. Brown rockfish fillets will not be analyzed for the HHRA exposure analysis because brown rockfish will constitute a small fraction of the fish/shellfish consumption scenario, only whole-body samples will be used as a conservative surrogate, and individual fillets are not likely to provide sufficient tissue mass for the analysis of all COIs. The compositing design is listed in Table 3-2. The final compositing scheme for each species and tissue type will be determined in consultation between the EWG and EPA after completion of sample collection.

Table 3-2. Compositing design for target species

Target Species	Tissue Type	Specimen Size (cm)	Composite Area	No. of Specimens /Sample
Brown rockfish	whole body	≥ 20	sampling location	1
English sole	whole body	> 20	throughout EW	5
	fillet[a]			5
Cancrid crab (Dungeness, red rock, and slender)[a]	edible meat	> 9	throughout EW	10
	hepatopancreas[b]			10
Shiner surfperch	whole body	> 8	throughout EW	10
Juvenile English sole (surrogate for shiner surfperch)	whole body	9 – 16	throughout EW	10

TARGET SPECIES	TISSUE TYPE	SPECIMEN SIZE (cm)	COMPOSITE AREA	NO. OF SPECIMENS /SAMPLE
Coonstripe shrimp	whole body	any size	TBD	12
Blue mussel	whole body (soft tissue only)	any size	TBD	12

TBD – To be determined after sample collection in consultation between the EWG and EPA.

[a] Although three species of crabs may be collected, each composites will be comprised of a single species of crabs (i.e., crabs of different species will not be composited together).

[b] English sole fillets and crab hepatopancreas samples are necessary for the HHRA. They represent tissue types consumed by seafood consumers. Whole body crab concentrations are necessary for the ERA. They represent tissues consumed by predators and exposure to crabs themselves. Whole body crab concentrations will be calculated as a weighted average of edible meat and hepatopancreas concentrations.

EW – East Waterway

3.2.1 Statistical analysis to determine number of samples

The sample size formula for estimating a one-sided UCL for a mean (Zar, 1996, Equation 1) was generalized to compute sample sizes needed to estimate a 95UCL such that the UCL will be less than $p^* \overline{X}$ from the true mean with ((1-α)*100)% confidence (Equation 2).

$$n = \frac{s^2}{d^2}\left(t_{1-\alpha,n-1}\right)^2$$ **Equation 1**[3]

$$n = \frac{CV^2\left(t_{1-\alpha,n-1}\right)^2}{p^2}$$ **Equation 2**[4]

The expected CV for EW tissue chemical concentrations was estimated from total PCB (sum of detected Aroclor) whole-body concentrations in 2005 EW English sole, brown rockfish, sand sole, and shiner surfperch (Windward 2006a); and 2004, 2005, and 2006 LDW Remedial Investigation (RI) Pacific staghorn sculpin, shiner surfperch, and English sole whole body and Dungeness and slender crab edible meat and hepatopancreas total PCBs, arsenic, and cPAH tissue data (Anchor and King County 2006; Windward 2005, 2006b) (Table T2).[5] The CVs of the arithmetic tissue concentrations in these datasets were relatively low and ranged from < 0.01 to 1.5 for the different species, locations, and years. Shiner surfperch had some of the highest CVs.

[3] Where *s* is the standard deviation, *d* is the difference to be detected, *n* is the sample size, and *t* is the critical value for the Student-t distribution.

[4] Where CV is $s/\overline{X}$.

[5] arsenic and cPAH data were only available from the 2004 sampling event.

Table 3-3. Sample size and coefficient of variation (CV) in tissue concentrations of Total PCBs, Arsenic, and Total cPAHs for Dungeness crab, Pacific staghorn sculpin, shiner perch, and English sole from the Lower Duwamish River

Taxon	Data Used in Analysis	Total PCBs		Arsenic		Total cPAHs	
		N	CV	N	CV	N	CV
Lower Duwamish data							
Dungeness crab	2004 edible meat	7	0.16	7	0.35	7	0.15
	2004 hepatopancres	3	0.16	3	0.16	3	1.24
	2005 edible meat	3	0.00				
	2005 hepatopancres	3	0.05				
Sculpin	2004 whole body	24	0.57	24	0.40	24	0.62
	2004 Lipid Normalized whole body	24	0.67	24	0.36	24	0.63
	2005 whole body	4	0.20				
	2005 Lipid Normalized whole body	4	0.15				
Shiner surfperch	2004 and 2005	46	1.5				
	Tissue 2004	24	1.5	24	0.18	24	0.62
	Total Tissue PCB 2004 (T2E individuals)	11	0.45				
	Total Tissue PCB 2004 (T2E recalc)	24	0.97				
	Lipid Normalized Tissue 2004	24	1.21	24	0.30	24	0.66
	Lipid Normalized Tissue 2004 (T2E recalc)	24	1.04				
	Total Tissue 2005	22	0.53				
	Lipid Normalized Tissue 2005	22	0.52				
English sole	2004 and 2005 whole body	42	0.49				
	2004 whole body	21	0.35	21	0.15	21	0.58
	2005 whole body	21	0.34				
	2006 T1 individual whole body	9	0.49				
East Waterway data							
English sole	calculated whole body	2	0.61				
	fillet composites	6	0.43				
	remainder composites	2	0.64				
Rockfish	individual whole body	2	0.51				
Sand sole	individual whole body	6	0.79				
Shiner surfperch	whole-body composites	3	0.79				

According to Singh et al. (2006) and Singh and Singh (2007) skewness of a lognormal variable, X is a function of the standard deviation of the log-transformed variable Y (Table T1). The maximum standard deviation of log transformed shiner surfperch tissue concentrations was 0.4 (Table T2) and so would qualify as mildly skewed according to Singh and Singh (2007).

Table 3-4. Skewness as a function of σ (or its *MLE*, sy = $\hat{\sigma}$), *sd* of log(*X*)

STANDARD DEVIATION	SKEWNESS
$\sigma < 0.5$	Symmetric to mild skewness
$0.5 \leq \sigma < 1.0$	Mild skewness to moderate skewness
$1.0 \leq \sigma < 1.5$	Moderate skewness to high skewness
$1.5 \leq \sigma < 2.0$	High skewness
$2.0 \leq \sigma < 3.0$	Extremely high skewness
$\sigma \geq 3.0$	Provides poor coverage

According to Singh et al. (2006):

> for mildly skewed lognormal or other distributions (with $sd = \sigma_y$ of log-transformed variable < 0.5), the difference between a UCL95 based upon Student's t-statistic (assuming a normal distribution) or any other parametric (Land's H-UCL) or nonparametric method (e.g., bias-corrected accelerated (BCA) bootstrap) is not of any practical significance. …
>
> for .. mildly skewed distributions …, there is no need to use a transformation to achieve symmetry ..., all parametric and nonparametric methods on raw data as well as on transformed data will yield similar and comparable results
>
> for values of standard deviation, σ_y, exceeding 1, the estimates and the UCL95 change drastically with a minor increase in standard deviation, σ_y of *Y*.

Given the low variance of existing data, it is likely that untransformed or log-transformed data could be used to compute UCLs for priority chemicals that are likely to be detected at most sampling locations.

Table 3-5. Standard deviation of different subsets of log transformed concentrations of PCBs in shiner surfperch .

	AREA	N	STD. DEVIATION
Log[Conc of Total PCBs in Tissue (ug/kg dw)]	1	12	0.17
	2	12	0.40
	3	12	0.32

	Area	N	Std. Deviation
	4	12	0.11
	Total	48	0.31
Log(Total Tissue PCB 2004, T2E recalc)	1	6	0.10
	2	6	0.15
	3	6	0.32
	4	6	0.08
	Total	24	0.28
Log(Lipid Normalized Tissue PCB 2004)	1	12	0.14
	2	12	0.30
	3	12	0.29
	4	12	0.17
	Total	48	0.28
Log(Lipid Normalized Tissue PCB 2004, T2E recalc)	1	6	0.17
	2	6	0.11
	3	6	0.35
	4	6	0.10
	Total	24	0.29
Log[Conc of Total PCBs in Tissue (ug/kg dw)]	1	6	0.10
	2	6	0.20
	3	6	0.21
	4	4	0.02
	Total	22	0.21
Log(Lipid Normalized Tissue PCB 2005)	1	6	0.14
	2	6	0.20
	3	6	0.17
	4	4	0.03
	Total	22	0.22

For more skewed populations, the Chebyshev Inequality[6] can be rearranged to compute sample size requirements for a one-sided 95UCL (Equation 3, 4 from Equation 2-46 in ProUCL Technical Guidance):

6 The two-sided Chebyshev theorem (Hogg and Craig, 1978) shown in Equation 2-44 from the ProUCL Technical Guidance ($P(-k\sigma_1 \le x - \mu_1 \le k\sigma_1) \ge 1-1/k_2$) leads to a two-sided UCL in Equation 2-45 (UCL = $\overline{X}$ +(1/α)sx/sqrt(n)) and a one-sided UCL in Equation 2-46 (UCL = $\overline{X}$ +((1/ α)-1)sx/sqrt(n)). The use of a one-sided UCL does not reduce the sample size as much for the nonparametric case as much as for the parametric case because it cannot be assumed that the two-sided confidence interval

$$n = \frac{s^2}{d^2}\left((1/\alpha) - 1\right)$$

Equation 3

$$n = \frac{CV^2((1/\alpha) - 1)}{p^2}$$

Equation 4

The lack of assumptions associated with the Chebyshev sample size calculation leads to considerably higher sample size estimates than if data can be assumed to be less skewed.

Using these two types of calculations, we found that 11 samples should provide a 95% UCL within a factor of ~0.8 of the mean (i.e., mean + 0.8x the mean) for all species with a CV ≤1.5 if the data are not highly skewed (Table T3). If the data are more highly skewed, 11 samples will provide a 95% UCL within a factor of 2 of the mean for all species with a CV ≤ 1.5 (Table T4).[7] If the CVs are ≤ 1.0, then 11 samples should be adequate to estimate a 95UCL within 0.60 or 1.3 times the mean for less-skewed and more-highly skewed data.

Table 3-6. Sample sizes needed to estimate a 95UCL within a precision factor of 0.25 to 2 times a mean for populations with CV ranging from 0.5 to 2 assuming data are only mildly skewed (based on normal theory)

	PRECISION FACTOR						
CV	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**1.5**	**2**
0.5	13	5	4	3	3	3	3
1	46	13	7	5	4	4	3
1.5	100	27	13	9	6	5	4
2	176	46	22	13	9	7	5

Table 3-7. Sample sizes needed to estimate a 95UCL within a precision factor of 0.25 to 2 times a mean for populations with CV ranging from 0.5 to 2 assuming data are more severely skewed (based on Chebyshev's inequality)

expressed in Equation 2-44 is symetrical. See also http://www.btinternet.com/~se16/hgb/cheb.htm#Graph2 for derivations of the one-sided UCL.

[7] A caveat to these sample sizes is that the theories of Singh, Maichle, and Lee (2006), the sample size calculations used, and UCL calculation procedures used in ProUCL 4.0 assume that all data in a data set come from a single population. If the East Waterway consists of fish that cannot be considered a single population due to differences in their exposure regimes or any other factors, these sample size calculations will not be valid.

	PRECISION FACTOR						
CV	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**1.5**	**2**
0.5	76	19	8	5	3	3	3
1	304	76	34	19	12	8	5
1.5	684	171	76	43	27	19	11
2	1216	304	135	76	49	34	19

3.2.2 Analyte list and mass requirements

COIs identified for the LDW are presented in Table 3-3. This list will provide a basis for the analyte list for the EW because sufficient tissue data do not currently exist to provide a site-specific list.

Table 3-3. COIs from LDW RI/FS

METALS	PAHS
Antimony	Acenaphthene
Arsenic (inorganic As and total As)	Acenaphthylene
Cadmium	Anthracene
Chromium	Benzo(a)anthracene
Cobalt	Benzo(a)pyrene
Copper	Benzo(b)fluoranthene
Lead	Benzo(g,h,i)perylene
Mercury	Benzo(k)fluoranthene
Molybdenum	Chrysene
Nickel	Dibenzofuran
Selenium	Dibenzo(a,h)anthracene
Silver	Fluoranthene
Thallium	Fluorene
Vanadium	Indeno(1,2,3-cd)pyrene
Zinc	Naphthalene
BUTYLTINS	Phenanthrene
Dibutyltin as ion	Pyrene
Tributyltin as ion	**PCBS**
Organochlorine Pesticides	Total PCBs (Aroclors and congeners)
4,4'-DDD	**DIOXINS AND FURANS**
4,4'-DDE	2,3,7,8 -TCDD
4,4'-DDT	1,2,3,7,8-PeCDD
Aldrin	1,2,3,4,7,8-HxCDD
alpha-BHC	1,2,3,6,7,8–HxCDD
gamma-BHC	1,2,3,7,8,9-HxCDD
Chlordane (alpha and gamma)	1,2,3,4,6,7,8-HpCDD
Dieldrin	OCDD
Endrin	2,3,7,8 -TCDF

Heptachlor	1,2,3,7,8-PeCDF
Methoxychlor	2,3,4,7,8-PeCDF
SVOCs	1,2,3,4,7,8-HxCDF
1,2-Dichlorobenzene	1,2,3,6,7,8–HxCDF
1,4-Dichlorobenzene	1,2,3,7,8,9-HxCDF
2-methylnaphthalene	2,3,4,6,7,8-HpCDF
2-Methylphenol	1,2,3,4,6,7,8-HpCDF
Benzoic acid	1,2,3,6,7,8,9-HpCDF
Benzyl alcohol	OCDF
Bis(2-ethylhexyl)phthalate	
Di-n-butyl phthalate	
Hexachlorobenzene	
Pentachlorophenol	
Phenol	

The analytical tissue methods and mass requirements for the COIs are presented in Table 3-4. Note that only a subset of samples will be analyzed for PCB congeners and dioxins and furans (The specific number or fraction of samples to be determined in consultation with EPA). The specific samples to be analyzed for PCB congeners and dioxins and furans will be determined after samples have been analyzed for PCB Aroclors. All samples will be analyzed for both total and inorganic arsenic because the HHRA uses only inorganic arsenic in the risk assessment, whereas, the ERA uses total arsenic. The tissue mass requirements for all analytes presented in Table 3-2 should also allow for all required laboratory quality assurance and quality control samples. Quality assurance and quality control are required for only a subset of samples, therefore, these tissue requirements are conservative. Additionally, a single homogenized aliquot of tissue mass may be used for more than one analysis (e.g., an extract may be split into two extract aliquots for PCB Aroclors and organochlorine pesticide analyses). If insufficient tissue mass is collected then, EWG will consult with EPA to identify the appropriate analytical strategy. Method modifications may include modified extraction techniques (e.g., adjusting the final extract volume), using a lower concentration for the lowest standard in the initial calibration, or adjusting the amount of extract injected into the instrument.

Table 3-4. Tissue mass required per sample type

ANALYTE	METHOD	TISSUE MASS (g)
PCB congeners	EPA 1668	25
Dioxin/furans[a]	EPA 1613	25
PCB Aroclors	EPA 8082	30
SVOCs (including PAHs, and phthalates)	EPA 8270D	30
Organochlorine pesticides[b]	EPA 8081A	25
Organochlorine pesticides confirmation[c]	EPA 1699 (modified)	25

ANALYTE	METHOD	TISSUE MASS (g)
Inorganic arsenic	EPA 1632	5
Mercury	EPA 7471A	2
Other metals[d]	EPA 6010B or EPA 6020	3
Tributyltin	Krone et al. (1989)	20
lipids	NOAA (1993)	5
total solids	PSEP (1986) or EPA 160.2	5
Total Mass		**200**

[a] A single aliquot of homogenized tissue mass may be used for the PCB congeners and dioxin/furans extraction. The extract would be split into two aliquots to undergo method specified cleanup techniques and analysis.

[b] A single aliquot of homogenized tissue mass may be used for the PCB Aroclors and the organochlorine pesticides extraction. The extract would be split into two aliquots to undergo method specified cleanup techniques and analysis.

[c] All extracts will be archived frozen, and detected pesticides and Aroclors may have their identification confirmed with GC/MS/MS by EPA 1699 (modified) at CAS, as necessary, to meet project needs.

[d] Antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, vanadium, zinc.

EPA – US Environmental Protection Agency
NOAA – National Oceanic and Atmospheric Administration
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PSEP – Puget Sound Estuary Program
SVOC – semivolatile organic compound

3.2.3 Sampling plan overview

Based on the optimal number of samples, the likely tissue mass for each species, the analytical tissue requirements, and the number of individuals permitted by WDFW, the target number of composite samples and number of specimens per composite was determined for each species. These target numbers, as well as the sampling location and size range for each target species and tissue type, are presented in Table 3-5.

Table 3-5. Sampling design for target species

Target Species	Specimen Size (cm)	Collection Method	Sampling Location	Tissue Type	No. of Analytical Samples	No. of Specimens/ Sample	Total No. of Individuals	No. of Specimens Permitted by WDFW	Estimated Tissue Mass/ Individual (g)	Estimated Tissue Mass/ Analytical Sample (g)
Brown rockfish[a]	≥ 20	scuba	riprap, pilings	whole body	11	1	11	25	> 200	250
English sole	> 20	trawl	random	whole body	11	5	55	110	200	1,000
				fillet	11	5	55		35	**175**
Cancrid crab (Dungeness, red rock, and slender)	> 9	trawl and trap	random	edible meat	6	10	60	60 requested	30	300
				hepato-pancreas	6	10			20	200
Shiner surfperch	> 8	trawl	random	whole body	6	10	60	60 requested	25	250
Juvenile English sole (surrogate for shiner surfperch)	9 – 16	trawl	random	whole body	6	10	60	60 requested	50	250
Coonstripe shrimp	any size	shrimp trap	random	whole body	11	12	132	140	15 – 30	**> 180**
Blue mussel	any size	scuba and by hand from pilings	random	whole body (soft tissue only)	11	12	132	140	15 – 30	**> 180**

[a] Brown rockfish fillets will not be analyzed for the HHRA exposure analysis only whole-body samples will be analyzed in order to minimize the number of rockfish collected. Whole body concentrations will be used in the HHRA and will be a conservative estimate of fillet concentrations..

WDFW – Washington State Department of Fish and Wildlife

Bold indicates that the tissue mass estimate is less than 200 g, the optimal amount for analysis of all analytes.

3.3 SAMPLE COLLECTION METHODS

The sampling methods for fish, crabs, shrimp and mussels include a high-rise otter trawl, crab and shrimp traps, SCUBA divers, or hand collection from a boat. Each sampling method, and which species are likely to be captured by each method, is described in more detail below. There may be contingencies during field activities that require modification of the general procedures outlined below. Modifications will be at the discretion of the FC after consultation with the Windward PM and the boat captain, if applicable. EPA will be consulted in the event that significant deviations from the sampling design are required. All modifications will be recorded in the logbook. This section also presents the location positioning, sample identification scheme and field equipment needed for each sampling collection method.

3.3.1 High-rise otter trawl

English sole, shiner surfperch, and crabs will be collected using a high-rise otter trawl. The high-rise otter trawl consists of a 25-ft (7.6-m) headrope and 29-ft (8.8-m) footline, 1.5-in. body mesh of No. 18 nylon twine, 1.25-in. cod-end mesh of No. 18 nylon twine, side panels that open to 5 ft at wing tips, and 24 x 36-in. V-shaped galvanized steel trawl doors. The footline is made of 0.5-in. combination poly/wire with 5.33-oz seine leads interspersed with 2-in. rubber discs, and the headrope has eight 5-in. plastic floats.

Because the EW is a small area, the distance over which a single trawl sample will be collected will vary (Map 3-1). Larger or smaller areas may be sampled based on initial catch results. Trawling will be conducted aboard the R/V *Kittiwake* using a "live sampling" technique, which will minimize the number of non-target species mortalities through species sorting and processing prioritization. Upon completion of an individual trawl tow, the catch will be hauled aboard and immediately emptied into a large plastic tub filled with running seawater. The date, time, and location of the tow will be recorded on the Fish and Crab Tissue Collection Form (Appendix B) after each trawl is hauled out of the water. Field technicians will sort the catch by species and size into numerous smaller tubs that also contain running seawater. Non-target species will be identified to species, measured to the nearest mm, and counted. Processing priority will be given to more sensitive species/life stages (e.g., juvenile salmonids, Pacific herring, smelt, juvenile tomcod) so as to return them to the EW as quickly as possible. Target species will be separated from non-target species. Gender of English sole will be determined in the field by holding the fish up to a light and observing if the organs extends back toward the tail of the fish, if so fish will be identified as females, if not, they will be identified as males or sexually immature. Shiner surfperch males will be identified in the field to the extent possible by dark coloration, presence of a bulbous gland posterior to the anal vent, and modified anal fins. Target fish will be processed as described in the fish processing section below (Section 3.4.1.4).

3.3.2 Crab and shrimp traps

In addition to the trawl, crabs will be collected using crab traps. Ladner 30-in. stainless steel rubber-wrapped crab traps will be deployed (12 traps per day) at locations throughout the EW (Map 3-1). Locations inaccessible to the trawl, such as under pier aprons and bridges, in slips, and along riprap slopes, will be targeted. Traps will be baited with a mixture of fish scraps and squid and deployed until target numbers of each target species are obtained or the maximum level of effort (i.e., 5 days) has been met. Priority will be given to the collection of Dungeness crabs, followed (in order) by red rock and slender crabs. However, few crabs were caught in trawls in 2005 (Windward 2006a), so all crabs of sufficient size will be kept unless it becomes clear that sufficient numbers of Dungeness or red rock crabs are available (see Section 2.3).

All traps will soak for from 4 to 8 hours and will be retrieved in the same order as they were deployed. The field crew will monitor the traps, to the extent possible. If few crabs have been collected after 4 hours on the first day of trapping, soak time on subsequent days will be increased to increase the likelihood of collecting target numbers of crabs. Any trap(s) determined by the FC to be a hazard to navigation will be moved to a new location away from potential traffic. Any traps lost during sampling will be replaced, and traps will be outfitted with a degradable latch to ensure that escape holes will open if a trap is lost. The degradable latch will ensure that lost traps will not continue to fish indefinitely and thereby harm local crab, shrimp, or fish. The date, time, and location of each trap will be recorded during both trap deployment and retrieval. Crab gender will be noted on the target species collection form at time of collection. Gender will determined by the width of the telson. Females have a wide telson, whereas males have a narrow telson.

Coonstripe shrimp will be collected using Ladner 30-in. nestable shrimp traps with 0.5-in. mesh. Shrimp traps will be deployed alongside crab traps using the same methods and level of effort described above for crab traps, except that shrimp pellet bait, rather than the bait described for crabs, will be used.

3.3.3 Scuba divers

Brown rockfish will be collected by scuba divers[8]. Eric Parker of Research Support Services, Inc., will do the sampling with the assistance of Seattle Aquarium diver, Jeff Christiansen. Both divers are fully qualified and willing to dive in all areas of the EW, excluding areas with condemned pilings. The scuba sampling will consist of two divers swimming transects along riprap and piling areas in areas deeper than 15 ft. (Map 3-1). In locations with pilings, divers will swim near the bottom of the pilings to capture any brown rockfish present. In riprap locations, beginning at the toe of the slope, divers will swim approximately 10 ft apart (or closer, if visibility is poor) along

[8] The primary method for collection of brown rockfish will be SCUBA divers; however, if insufficient numbers are collected by SCUBA divers any brown rockfish (>20 cm) encountered during trawling will be retained up to the target number.

approximately 400-ft-long transects, maintaining a constant depth. If a brown rockfish is encountered within a transect, it will be collected. If not, parallel transects, 20 ft shallower than the previous transect will be swum at the same location until a diver is within 15 ft of the surface. If a brown rockfish is collected in a given 400-ft-long survey area, the divers will move approximately 600 ft away along the same bank to begin the next survey. If no brown rockfish are encountered in a given transect, divers will move to the next adjacent area and begin sampling. Areas with active boat traffic will be avoided. Divers will be equipped with two-way radios and accompanied by a surface support boat. When brown rockfish are encountered, the divers will tell the surface support boat. The depth reported by the divers and location of the diver's bubbles will be recorded by the surface support crew using a global positioning system (GPS). The surface support crew will also record all transects surveyed and whether brown rockfish were encountered. If, after all subtidal riprap and piling locations have been surveyed, the divers have not collected the targeted number of 11 rockfish (see Section 3.2, they will return to locations where brown rockfish were previously observed or areas adjacent to those where brown rockfish were collected. Sampling will not occur in areas where there are condemned pilings (i.e., the southern end of Terminal 25 and south of Slip 36 (Map 3-1). Brown rockfish will be collected by deploying small neutrally buoyant barrier nets near brown rockfish and chasing the fish into the nets. The divers will positively identify the fish as brown rockfish before surfacing in order to ensure that copper and quillback rockfish are not accidentally injured during sampling. A Hawaiian sling (harpoon gun) may be used if collection using nets is infeasible.

3.3.4 Mussel collection

Mussels will be collected by hand from a boat. Mussels will be collected from pilings and sheetpile locations throughout the EW. Collection will take place in August, 2008. Prior to collection, a survey will be conducted of all accessible areas by boat and record locations where mussels are located. In addition, divers will note all locations that mussels are present during the rockfish survey. Equal quantities of mussels from several randomly selected areas throughout the EW will be collected to meet the target number of 132 mussels (see Section 3.1.5). Mussels will be removed from pilings and sheetpile by hand using pliers and a knife. If insufficient numbers of mussels can be collected over this 2-day time period, EWG will consult with EPA and stakeholders to determine whether or not additional mussel sampling is warranted.

3.3.5 Location positioning

Sampling locations will be documented using a differential global positioning system (DGPS). A handheld DGPS unit will be used during deployment of crab and shrimp traps and a DGPS unit mounted on the winch arm will be used with equipment deployed from a sampling vessel and during the collection of mussels. The DGPS unit is wide-area augmentation system (WAAS) enabled and will receive DGPS signals from satellites to both triangulate a position and provide a locational correction factor,

resulting in positioning accuracy of within 3 m. Washington State Plane coordinates North (NAD 83) will be used for the horizontal datum.

3.3.6 Identification scheme for all locations and samples

Unique alphanumeric identification (ID) numbers will be assigned to each individually wrapped fish and crab specimen in the field and recorded on the Target Species Tally Form (Appendix B). Organisms other than the targeted fish and crab species will be recorded on the Non-Target Species Tally Form (Appendix B), but no specimen ID will be assigned. The first two characters of the ID will be "EW" to identify the project area. The next two characters will be "08" to indicate that the sample was collected in 2008. The next five characters will identify the collection method and effort number: TR representing trawl, CT representing crab trap, ST representing shrimp trap, or HC representing hand collection, SB representing SCUBA, followed by a three-digit number representing the effort number, numbered sequentially (e.g., the 15th trawl after the start of sampling would be TR015). The next two characters will identify the individual species type: English sole (ES), shiner surfperch (SS), Dungeness crab (DC), red rock crab (RR), slender crab (SC), brown rockfish (BR), shrimp (SR), or mussel (MS). The next identifier will be numeric and indicate the sequential number of the specimen captured. As an example, the 5th English sole captured in the 15th trawl would be identified as EW-08-TR015-ES-05. All relevant information for each individually wrapped and labeled target specimen, including specimen ID, length, weight, external abnormalities, sample date, time, and location number will be recorded on the Target Species Tally Form and included as an appendix to the data report. All pertinent data associated with each individual fish or crab specimen will be traceable.

Once samples are composited in the lab, a unique sample number will be assigned to the composite. Fish and crab composite tissue samples will be identified using a similar convention, with the following differences. Effort number will not be indicated because specimens from multiple efforts may be included in each composite sample. Tissue type will be indicated as whole body (WB), skin-on fillet (FL), hepatopancreas (HP), or edible meat (EM); each sample for a given species and sampling area combination will be numbered sequentially following the letters "comp." Corresponding hepatopancreas and edible meat samples will be assigned the same composite number. For example, the first Dungeness crab edible meat composite sample would be identified as EW-08- DC-EM-comp1; and the corresponding hepatopancreas sample would be identified as EW-08- DC-HP-comp1. Brown rockfish will not be combined in composite samples so each sample will be identified using the individual fish identifiers.

3.3.7 Field equipment

The items needed in the field for each sampling method are identified in Table 3-6. The FC will check that all equipment is available and in working order each day before sampling personnel go into the field.

Table 3-6. Field equipment for fish, crab, and mussel tissue collection

Field Equipment	Fish Collection	Crab and Shrimp Collection	Mussel Collection
QAPP	X	X	X
Health and safety plan	X	X	X
Key personnel contact information list	X	X	X
Field collection forms	X	X	X
Field notebooks (Rite in the Rain®)	X	X	X
Chain-of-custody forms	X	X	X
Pens, pencils, Sharpies®	X	X	X
Tide tables	X	X	X
Study area maps	X	X	X
Fish identification guides	X	X	
GPS (with extra batteries)	X	X	X
Digital camera	X	X	X
Cellular phone	X	X	X
Marine radio	X	X	
Alconox® detergent	X	X	X
Scrub brushes	X	X	X
Paper towels	X	X	X
Garbage bags	X	X	X
Buckets (5 and 2 gallon)	X	X	X
Coolers	X	X	X
perforated plastic jars		X	
Ice (wet and dry)	X	X	X
Heavy-duty aluminum foil	X	X	X
Zip-lock freezer bags (assorted sizes)	X	X	X
Plastic bins for specimen sorting	X	X	
Dip nets	X		
Calipers	X	X	X
Measuring boards	X	X	
Scales	X	X	
Ladner 30-in. crab traps (complete with floats, line, bait bags/jars, and weights)		X	
Ladner 30-in. shrimp traps (complete with floats, line, bait bags/jars, and weights)		X	
Bait for crab/shrimp traps		X	

Field Equipment	Fish Collection	Crab and Shrimp Collection	Mussel Collection
Pike pole (for dislodging nets hung on underwater debris and trap retrieval)	X	X	
Cutting board		X	
Knife		X	
High-rise otter trawl net	X	X	
Powder-free nitrile exam gloves	X	X	X
Rubber work gloves	X	X	X
Rubber boots	X	X	X
Rain gear	X	X	X
Waders		X	X
Personal flotation devices	X	X	
Hard hats	X		
Head lamps	X	X	
First aid kit	X	X	X
Duct tape	X	X	X

GPS – global positioning system
QAPP – quality assurance project plan

3.4 Sample Handling and Custody Requirements

This section describes how individual samples will be processed, labeled, tracked, stored, and transported to the laboratory for analyses.

3.4.1 Sample handling procedures

3.4.1.1 Fish and crab samples

Specimens will be stored frozen at ARI until they are homogenized and composited. During the compositing and homogenization process, fish and crab specimens from each trawl, trap, or sampling location will be kept separate from one another and processed one at a time to ensure that individual specimens are tracked properly. Each individual of the target species will be re-weighed using an analytical scale accurate to 0.5 g. In keeping with EPA guidance, crab carapace width measurements will be made laterally across the carapace from tip of spine to tip of spine (EPA 2000a). Tissue dissection and homogenization will be performed by qualified laboratory technicians following ARI's standard operating procedures (SOPs) under Windward's oversight. All equipment used for fish processing must be completely disassembled and cleaned prior to initial use and after each composite sample to ensure that no cross-contamination occurs, in accordance with the laboratory's SOP.

For fillet samples, partially thawed whole fish will be filleted with the skin on. A lengthwise cut will be made along the dorsal region adjacent to the spine using a solvent-rinsed scalpel or pre-cleaned razor blade. The muscle tissue will be carefully separated from the ribs until the entire muscle fillet has been removed, including all

tissue behind the gill flap to the tail fin (as much as is reasonably possible). Care must be taken to not puncture any internal organs during this process.

The crab samples will be partially thawed before processing. The hepatopancreas tissue and edible-meat tissue will be dissected and separated into respective samples using surgical scalpels, forceps, shears, picks, and/or razor blades. The shell will be removed from the belly of the crab by pulling up on the back end of the shell, thereby exposing the crab's internal organs. The hepatopancreas tissue, which is yellow, will be removed, ensuring separation from all other tissue (e.g., white, spongy gill tissue). All edible-meat tissue (as much as is reasonably possible) will be removed from the crab's upper body and legs.

The gender of brown rockfish will be identified prior to homogenizing using the following EPA (2000b) method. "An incision will be made on the ventral surface of the body from a point immediately anterior to the anus toward the head to a point immediately posterior to the pelvic fins. If necessary, a second incision should be made on the left side of the fish from the initial point of the first incision toward the dorsal fin. The resulting flap should be folded back to observe the gonads. Ovaries appear whitish to greenish to golden brown and have a granular texture. Testes appear creamy white and have a smooth texture (Texas Water Commission, 1990). The sex of each fish should be recorded on the sample processing form."

All specimens will be homogenized using a blender, chopper, and/or meat grinder. The tissue may be cut with solvent-rinsed knives or razor blades into smaller pieces (i.e., 3-in. slices) prior to chopping or blending to ensure that the tissue is homogenized into a creamy paste with no discernable bits remaining (e.g., no large pieces of bones or fins). The composited, homogenized tissue sub-sample selected for extraction or analysis must be representative of the entire fish composite sample. The final homogenization and compositing scheme will be determined in consultation between the EWG and EPA.

3.4.1.2 Shrimp and mussel samples

Mussel and shrimp specimens for chemical analysis will be wrapped individually in foil and placed in zip-lock bags for delivery to ARI. Mussel and shrimp specimens will be processed, composited, and homogenized by qualified laboratory personnel at ARI according to the laboratory's SOPs. The whole-body mussel tissue will be removed from the shells prior to homogenization using a stainless steel spatula or knife. Mussels will be frozen prior to processing. Any excess liquid will be collected as part of the thawed sample because some cells may have lysed during freezing and released material from the tissues. Care should be taken to remove all tissue from the shell, including the entire mantle. Once removed from the shell, all tissue will be homogenized using a blender or chopper. It may be necessary to cut or cube some of the tissues before blending or chopping. All equipment must be cleaned before use and between samples in accordance with the laboratory's SOPs. The final

homogenization and compositing scheme will be determined in consultation between the EWG and EPA.

Sample labels will be waterproof and self-adhering. Each sample label will contain the project number, sample identification, analyses, date, and time of collection, and initials of the individual(s) preparing the sample. A completed sample label will be affixed to each sample container. The labels will be covered with clear tape immediately after they have been completed to protect them from being stained or soiled from water.

3.4.2 Sample tracking and custody procedures

Sample labels will contain the project number, name(s) of sampling personnel, date, time, specimen ID, and comments. The specimens included in each composite sample will be tracked using the Composite Sample Form (Appendix B). This form will include the project number, the composite sample ID, the sample ID of each specimen included in the composite sample, collection date and time, and the weight of each specimen.

At each laboratory, a unique identifier will be assigned to each sample (using either the project ID or laboratory ID). The laboratory will ensure that a sample tracking record follows each sample through all stages of laboratory processing. The sample tracking record must contain, at a minimum, the name or initials of individuals responsible for performing the analyses, dates of sample extraction/preparation and analysis, and the type of analysis being performed.

Custody procedures will be used for all samples throughout the collection, transport, and analytical process. Custody procedures will be initiated during sample collection. A chain-of-custody form will accompany samples to the analytical laboratory. Each person who has custody of the samples will sign the chain-of-custody form and ensure that the samples are not left unattended unless properly secured.

3.4.3 Sample custody procedures

Samples are considered to be in custody if they are: 1) in the custodian's possession or view, 2) retained in a secured place (under lock) with restricted access, or 3) placed in a container and secured with an official seal(s) such that the sample cannot be reached without breaking the seal(s). Custody procedures will be used for all samples throughout the collection, transport, and analytical process. Custody procedures will be initiated during sediment and tissue sample collection. A chain-of-custody (COC) form will accompany samples to the analytical laboratory. Each person who has custody of the samples will sign the COC form and ensure that the samples are not left unattended unless properly secured. Minimum documentation of sample handling and custody will include:

- project name and unique sample number
- sample collection date and time

- any special notations on sample characteristics or problems
- initials of the person collecting the sample
- date sample was sent to the laboratory
- shipping company name and waybill number

The FC will be responsible for all sample tracking and custody procedures for samples in the field. The FC will be responsible for final sample inventory and will maintain sample custody documentation. The FC will also complete COC forms prior to removing samples from the sampling area. At the end of each day, and prior to transfer, COC entries will be made for all samples. Information on the labels will be checked against sample log entries, and sample tracking forms and samples will be recounted. COC forms will accompany all samples. The COC forms will be signed at each point of transfer. Copies of all COC forms will be retained and included as appendices to the data reports. Tissue and sediment samples will be shipped or hand delivered in sealed coolers with custody seals to the analytical laboratories.

The laboratories will ensure that COC forms are properly signed upon receipt of the samples and will note questions or observations concerning sample integrity on the COC or other sample receipt forms. The laboratories will contact the FC or Project QA/QC Coordinator immediately if discrepancies are discovered between the COC forms and the sample shipment upon receipt.

The laboratory will ensure that a sample tracking record follows each sample through all stages of laboratory processing. The sample tracking record for chemistry samples must contain, at a minimum, the name/initials of individuals responsible for performing the analyses, dates of sample extraction/preparation and analyses, and the types of analyses being performed.

3.4.5 Shipping requirements

Sample coolers containing fish and shellfish specimens will be transported directly to ARI. Subsamples of the homogenized composite samples will be shipped in sturdy coolers with ice or frozen gel packs to Analytical Perspectives, Brooks Rand, and/or CAS. The temperature inside the cooler(s) containing chemistry samples will be checked by the laboratory upon receipt of the samples. The laboratory will specifically note any coolers that do not contain ice packs or that are not sufficiently cold (4° ± 2°C) upon receipt. Each sample will be assigned a unique laboratory number, and samples will be grouped in appropriate sample delivery groups (SDGs).

Samples will be assigned a specific storage area within the laboratory and will be kept there until analyzed. Tissues will be frozen upon receipt until analysis. The analytical laboratory will not dispose of the environmental samples for this project until notified in writing by the project QA/QC coordinator.

3.5 ANALYTICAL METHODS

After field collection, samples will been sent to ARI for processing (e.g., filleting, shucking), compositing, homogenization, and chemical analysis. Sub-samples of selected tissue sample homogenates will be shipped frozen from ARI to Analytical Perspectives for PCB congener and dioxin/furan analysis, Brooks Rand for inorganic arsenic analysis, and CAS for confirmational pesticide analysis (Table 3-7). This section provides a brief summary of the analytical methods.

Table 3-7. Procedures to be conducted at each analytical laboratory

ARI	ANALYTICAL PERSPECTIVES	BROOKS RAND	CAS
Tissue homogenization and compositing PCB Aroclors Organochlorine pesticides SVOCs Metals including mercury Tributyltin Lipids Moisture	PCB congeners Dioxins and furans	Inorganic arsenic	Organochlorine pesticides[a]

[a] GC/MS/MS pesticide analysis may be conducted on a subset of samples at CAS following an examination of the initial pesticide and Aroclor results.

ARI – Analytical Resources, Inc.

CAS – Columbia Analytical Services, Inc.

PCB – polychlorinated biphenyl

SVOC – semivolatile organic compound

Homogenates may be frozen; however, frozen homogenates from individual fish must be re-homogenized before compositing for analysis (if required). Any remaining homogenates or whole fish will be archived frozen for a maximum of 1 year after collection.

All composite tissue samples will be analyzed for PCBs as Aroclors, semivolatile organic compounds (SVOCs), metals, inorganic arsenic, tributyltin, lipids, and total solids (Table 3-8). A subset of samples will be analyzed for PCB congeners and dioxins/furans. The specific samples selected for PCB congener and dioxin/furan analysis will be determined based on the PCB Aroclor data. If organochlorine pesticides are detected in samples analyzed by method EPA 8081A, which utilizes gas chromatography/electron capture detection (GC/ECD), then some samples may be selected for confirmatory analyses by gas chromatography/mass spectrometry/ mass spectrometry (GC/MS/MS) at CAS by method EPA 1699 (modified). The samples selected for confirmatory analysis will be identified in consultation with EPA. The confirmatory GC/MS/MS test method is not subject to analytical interferences by PCB congeners, and is therefore more accurate for identifying and quantifying pesticides than the GC/ECD test method. The data generated during the confirmatory analyses shall be selected as the final result for the associated samples, unless specific QA/QC

concerns arise relevant to the analyses. The confirmatory analyses will extract and analyze unique subsamples of the homogenized tissue mass, with the assumption that the chemical concentrations in each homogenized subsample are representative and equivalent to the chemical concentrations of the composite sample as a whole.

Table 3-8. Numbers of tissue samples to be analyzed for each analyte group

Analyte	Number of Composite Tissue Samples by Species and Type							
	English Sole		Brown Rockfish	Shiner Surfperch	Crab		Mussel	Shrimp
	WB	Fillet	WB	WB	Edible Meat	Hepato-pancreas	WB	WB
PCB congeners	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Dioxins/furans[a]	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
PCB Aroclors and organochlorine pesticides[a]	11	11	11	6	6	6	11[b]	11[b]
SVOCs (including PAHs)	11	11	11	6	6	6	11[b]	11[b]
Mercury	11	11	11	6	6	6	11[b]	11[b]
Other metals, including total arsenic	11	11	11	6	6	6	11[b]	11[b]
Inorganic arsenic	11	11	11	6	6	6	11[b]	11[b]
Tributyltin	11	11	11	6	6	6	11[b]	11[b]
lipids, total solids	11	11	11	6	6	6	11[b]	11[b]

[a] GC/MS/MS pesticide analysis may be conducted on a subset of samples at CAS if sufficient sample mass is available.

[b] Number represents the maximum number of samples, actual number will depend on the number of organisms collected.

PAH – polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

SVOC – semivolatile organic compound

TBD – to be determined in consultation with EPA

WB – whole body

The laboratories will store the tissue homogenate samples frozen. Analytical methods and laboratory sample handling requirements are presented in Table 3-9.

Table 3-9. Analytical methods and sample handling requirements for tissue samples

Parameter	Method	Reference	Laboratory	Maximum Sample Holding Time	Container	Method of Preservation
PCBs as Aroclors	GC/ECD	EPA 8082A	ARI	1 year to extract, 40 days to analyze	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
PCB congeners	HRGC/HRMS	EPA 1668	Analytical Perspectives	1 year to extract, 40 days to analyze	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Dioxins and furans	HRGC/HRMS	EPA 1613B	Analytical Perspectives	1 year to extract, 40 days to analyze	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Organochlorine pesticides[a]	GC/ECD	EPA 8081A	ARI	1 year to extract, 40 days to analyze	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Organochlorine pesticides[a]	GC/MS/MS	EPA 1699 (modified)	CAS	1 year to extract, 40 days to analyze	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
SVOCs including PAHs[b]	GC/MS	EPA 8270D	ARI	1 year to extract, 40 days to analyze	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Inorganic arsenic	HG-AFS	EPA 1632	Brooks Rand	6 months	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Mercury	CVAA	EPA 7471	ARI	60 days	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Total metals[c]	ICP/MS, ICP/AES, or GFAAS	EPA 6020, 6010B, or 7000	ARI	6 months	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Tributyltin, dibutyltin, monobutyltin (as ions)	GC/FPD	Stallard et al. (1988)	ARI	1 year to extract, 40 days to analyze	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Lipids	DCM: acetone extraction gravimetric	NOAA (1993)	ARI	1 year	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C
Total solids	freeze-dried	PSEP (1997a)	ARI	6 months	aluminum foil (whole fish) glass jar (homogenate)	freeze/-20 °C

[a] Target pesticides include: 4,4′-DDT, 4,4′-DDE, 4,4′-DDD, 2,4′-DDT, 2,4′-DDE, 2,4′-DDD, aldrin, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, oxychlordane, alpha- and gamma-chlordane, cis- and trans-nonachlor, dieldrin, endosulfan, endosulfan sulfate, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, mirex, and toxaphene.

[b] Target PAHs include: anthracene, pyrene, dibenzofuran, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, perylene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benzo(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, 2-methylnaphthalene.

[c] Arsenic, antimony, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc.

ARI – Analytical Resources, Inc.

BHRAA –borohydride reduction atomic absorption

CAS – Columbia Analytical Services, Inc.

CVAA – cold vapor atomic absorption

DCM – dichloromethane

GC/ECD – gas chromatography/electron capture detector

GC/FPD – gas chromatography/flame photometric detection

GC/MS – gas chromatography/mass spectrometry

GC/MS/MS – gas chromatography/mass spectrometry/mass spectrometry

GFAAS – graphite furnace atomic absorption spectrophotometry

HRGC/HRMS – high resolution gas chromatography/high resolution mass spectrometry

HG/AFS – hydride generation/atomic fluorescence spectrometry

ICP/AES – inductively couple/plasma atomic emission spectrometry

ICP/MS – inductively coupled/plasma mass spectrometry

PAH – polycyclic aromatic hydrocarbon

PSEP – Puget Sound Estuary Program

SIM – select ion monitoring

SVOC – semivolatile organic carbon

The parameters used to assess data quality are precision, accuracy, representativeness, comparability, completeness, and sensitivity. Table 3-10 lists specific data quality indicators (DQIs) for the laboratory analysis of all samples. These parameters are discussed in more detail in the following subsections. Target MDLs and RLs are presented in Appendix D. Interferences in individual samples may result in an increase in the reported quantitation limits. To achieve the required low quantitation limits, some modifications to the methods may be necessary. Composite samples for analysis should weigh at least 200 g to meet the target RLs. Table 3-11 summarizes the QC procedures to be performed by the laboratory.

Table 3-10. Data quality indicators for tissue analyses

Parameter	Precision (Laboratory Replicates)	Accuracy		Completeness
		Instrument Calibration (% Difference)	Spiked Samples (% Recovery)	
PCBs as Aroclors	±50%	±25	laboratory QC limits[a]	95%
Organochlorine pesticides	±50%	±25	laboratory QC limits[a]	95%
SVOCs including PAHs	±50%	±25	laboratory QC limits[a]	95%
PCB congeners	±50%	±15	laboratory QC limits[a]	95%
Dioxins and furans	±50%	±25	laboratory QC limits[a]	95%
Total mercury	±30%	±20	75 – 125	95%
Other total metals	±30%	±10	75 – 125	95%
Inorganic arsenic	±25%	±20	75 – 125	95%
Butyltins	±50%	±15	laboratory QC limits[a]	95%
Lipids	±30%	na	na	95%
Grain size	±30%	na	na	95%
Total solids	±20%	na	na	95%
TOC	±30%	na	laboratory QC limits[a]	95%

[a] The laboratory's performance-based control limits that are in effect at the time of analysis will be used as the accuracy limits for LCS and MS/MSD samples.

PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
QC – quality control
TOC – total organic carbon
SVOC – semivolatile organic compound

3.5.1 Precision

Precision is the measure of the reproducibility among individual measurements of the same property, usually under similar conditions, such as multiple measurements of the same sample. Precision is assessed by performing multiple analyses on a sample and is expressed as an RPD when duplicate analyses are performed and as %RSD when more than two analyses are performed on the same sample (e.g., triplicates). Precision is assessed by laboratory duplicate analyses (e.g. laboratory replicate samples, MS/MSD, LCS duplicates) for all parameters except in cases when reference

materials are not available or spiking of the matrix is inappropriate. In these cases, precision is assessed by laboratory triplicate analyses. Precision measurements can be affected by the nearness of a chemical concentration to the MDL, where the percent error (expressed as either %RSD or RPD) increases. The DQI for precision varies depending on the analyte (Table 3-10). The equations used to express precision are as follows:

$$RPD = \frac{(\text{measured conc} - \text{measured duplicate conc})}{(\text{measured conc} + \text{measured duplicate conc}) \div 2} \times 100 \qquad \textbf{Equation 1}$$

$$\%RSD = (SD/D_{ave}) \times 100 \qquad \textbf{Equation 2}$$

where:

$$SD = \sqrt{\left(\frac{\sum (D_n - D_{ave})^2}{(n-1)}\right)}$$

SD = standard deviation
D = sample concentration
D_{ave} = average sample concentration
n = number of samples

3.5.2 Accuracy

Accuracy is an expression of the degree to which a measured or computed value represents the true value. Accuracy may be expressed as a percentage recovery for MS and LCS analyses. The DQI for accuracy varies, depending on the analyte (Table 3-10). Below is the equation used to express accuracy for spiked samples:

$$\text{Percent recovery} = \frac{\text{spike sample result} - \text{unspiked sample result}}{\text{amount of spike added}} \times 100 \qquad \textbf{Equation 3}$$

3.5.3 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent an environmental condition. The sampling approach was designed to address the specific objectives described in Section 2.2. Assuming those objectives are met, the samples collected should be considered adequately representative of the environmental conditions they are intended to characterize.

3.5.4 Comparability

Comparability expresses the confidence with which one dataset can be evaluated in relation to another dataset. The sample collection and chemical and physical testing will adhere to the most recent Puget Sound Estuary Program (PSEP) QA/QC procedures (1997b) and EPA and PSEP analysis protocols.

3.5.5 Completeness

Completeness is a measure of the amount of data that is determined to be valid in proportion to the amount of data collected. Completeness will be calculated as follows:

$$\text{Completeness} = \frac{\text{number of valid measurements}}{\text{total number of data points planned}} \times 100 \qquad \textbf{Equation 4}$$

The DQI for completeness for all components of this project is 95%. Data that have been qualified as estimated because the QC criteria were not met will be considered valid for the purpose of assessing completeness. Data that have been qualified as rejected will not be considered valid for the purpose of assessing completeness.

3.5.6 Sensitivity

Analytical sensitivity is the minimum concentration of an analyte above which a data user can be reasonably confident that the analyte was reliably detected and quantified. Standard tissue mass requirements to meet the target MDLs and RLs for each particular analytical method are specified in Appendix D. MDLs and RLs are compared to risk-based ACGs in Appendix D.

3.6 QUALITY ASSURANCE/QUALITY CONTROL

The QA/QC criteria for the laboratory analyses are described below.

3.6.1 Chemical analyses quality control criteria

Before analyzing the samples, the laboratory must provide written protocols for the analytical methods to be used, calculate MDLs for each analyte in each matrix type, and establish an initial calibration curve for all analytes. The laboratory must demonstrate their continued proficiency through the participation in inter-laboratory comparison studies and through repeated analysis of SRMs, calibration checks, method blanks, and spiked samples.

3.6.1.1 Determination of MDLs

The MDL is defined as the lowest concentration of an analyte or compound that a method can detect in either a sample or a blank with 99% confidence. The laboratories determine MDLs using standard procedures outlined in 40CFR136, in which seven or more replicate samples are fortified at 1 to 5 times (but not to exceed 10 times) the expected MDL concentration. The MDL is then determined by calculating the standard deviation of the replicates and multiplying by the Student's t-factor (e.g., 3.14 for seven replicates).

3.6.1.2 Sample delivery group

Project- and/or method-specific quality control measures such as MS/MSD or laboratory replicate samples will be analyzed per SDG, preparatory batch, or analytical batch, as specified in Table 3-11. An SDG is defined as no more than

20 samples or a group of samples received at the laboratory within a 2-week period. Although a SDG may span 2 weeks, all holding times specific to each analytical method will be met for each sample in the SDG.

Table 3-11. Laboratory quality control sample analysis summary

Analysis Type	Initial Calibration	Second Source Initial Calibration Verification	Continuing Calibration Verification	Laboratory Control Sample	Laboratory Replicate Sample	Matrix Spike	Matrix Spike Duplicate	Method Blank	Standard Reference Material[a]	Surrogate Spike
PCB Aroclors	prior to analysis	after initial calibration	every 10 to 20 analyses or 12 hrs	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each batch or SDG	each sample
PCB congeners and dioxins/furans	prior to analysis	after initial calibration	prior to 12-hr analytical batch	1 per prep batch	na	na	na	1 per prep batch	na	each sample
Organochlorine pesticides[b]	prior to analysis	after initial calibration	every 10 to 20 analyses or 12 hrs	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each batch or SDG	each sample
Mercury	prior to analysis	after initial calibration	every 10 samples	1 per prep batch	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	each batch or SDG	na
Other metals, including inorganic arsenic	prior to analysis	after initial calibration	every 10 samples	1 per prep batch	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	each batch or SDG	na
SVOCs, including PAHs	prior to analysis	after initial calibration	every 10 to 20 analyses or 12 hrs	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each batch or SDG	each sample
Butyltins	prior to analysis	after initial calibration	every 10 samples	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	Each batch or SDG	each sample
Percent solids	na	na	na	na	1 per batch or SDG	na	na	1 per prep batch	na	na
Lipids	na	na	na	na	1 per batch or SDG	na	na	na	na	na

Note: A batch is a group of samples of the same matrix analyzed or prepared at the same time, not to exceed 20 samples.

[a] An LCS may be used to assess accuracy when an SRM is unavailable.

[b] Aroclor standards will be run as interference check samples for this analysis (excluding EPA 1699 modified analyses).

na – not applicable
PCB – polychlorinated biphenyl
PAH – polycyclic aromatic hydrocarbon
SDG – sample delivery group
SIM – selected ion monitoring
SVOC – semivolatile organic compound
TOC – total organic carbon

3.6.1.3 Laboratory quality control criteria

The analyst will review results of QC analyses (described below) from each analytical batch immediately after the samples have been analyzed. The QC sample results will be evaluated to determine whether control limits have been exceeded. If control limits are exceeded, then appropriate corrective action must be initiated, such as recalibration followed by reprocessing of the affected samples, before a subsequent group of samples is processed. The project QA/QC coordinator must be contacted immediately by the laboratory PM if satisfactory corrective action to achieve the DQIs outlined in this QAPP is not possible. All laboratory corrective action reports relevant to the analysis of project samples must be included in the data deliverable packages.

All primary chemical standards and standard solutions used in this project will be traceable to the National Institute of Standards and Technology, Environmental Resource Associates, National Research Council of Canada, or other documented, reliable, commercial sources. The accuracy of the standards should be verified through comparison with an independent standard. Laboratory QC standards are verified a multitude of ways. Second-source calibration verifications (i.e., same chemicals manufactured by two different vendors) are analyzed to verify initial calibrations. New working standard mixes (e.g., calibrations, spikes) should be verified against the results of the original solution before being put into use and be within 10% of the true value. Newly purchased standards should be verified against current data. Any impurities found in the standard must be documented. The following sections summarize the procedures that will be used to assess data quality throughout sample analysis. Table 3-11 summarizes the QC procedures to be performed by the laboratory. The associated control limits for precision and accuracy are summarized in Table 3-10.

Laboratory Replicate Samples

Laboratory replicate samples provide information on the precision of the analysis and are useful in assessing potential sample heterogeneity and matrix effects. Laboratory replicates are subsamples of the original sample that are prepared and analyzed as a separate sample, assuming sufficient sample matrix is available. A minimum of one laboratory replicate sample will be analyzed for each SDG or for every 20 samples, whichever is more frequent, for inorganic and conventional parameters.

Matrix Spikes and Matrix Spike Duplicates

The analysis of MS samples provides information on the extraction efficiency of the method on the sample matrix. By performing MSD analyses, information on the precision of the method is also provided for organic analyses. For organic analyses, a minimum of one MS/MSD pair will be analyzed for each SDG, when sufficient sample volume is available, with the exception of PCB congeners and dioxins and furans. MS/MSD samples are not analyzed for PCB congeners and dioxins and furans. For

inorganic analyses (i.e., metals), a minimum of one MS sample will be analyzed for each SDG, when sufficient sample volume is available.

Method Blanks

Method blanks are analyzed to assess possible laboratory contamination at all stages of sample preparation and analysis. A minimum of one method blank will be analyzed for each extraction/digestion batch or for every 20 samples, whichever is more frequent.

Standard Reference Material

SRMs are samples of similar matrix and of known analyte concentration that are processed through the entire analytical procedure and used as an indicator of method accuracy. A minimum of one SRM will be analyzed for each sample group or for every 20 samples, whichever is more frequent.

Surrogate Spikes

All samples analyzed for organic compounds will be spiked with appropriate surrogate compounds as defined in the analytical methods.

Laboratory Control Samples

LCSs are prepared from a clean matrix similar to the project samples that are spiked with known amounts of the target compounds. The recoveries of the compounds are used as a measure of the accuracy of the test methods.

Interference Check Samples

In order to identify specific organochlorine pesticides that may coelute with PCB congeners, single point mid-concentration PCB standards (Aroclors 1248, 1254, and 1260) should be run regularly with single-component pesticides in the initial calibration. Additional Aroclors should be analyzed if they are detected in project samples. The resulting data will be reviewed by data validators in order to assess potential interference issues affecting the reported pesticide results.

Internal Standard Spikes

Internal standards may be used for calibrating and quantifying organic compounds and metals using ICP/MS. If internal standards are used, all calibration, QC, and project samples will be spiked with the same concentration of the selected internal standard(s). Internal standard recoveries and retention times must be within method and/or laboratory criteria.

Method of Standard Additions

If matrix interferences are found to be present during metals analysis, it may be necessary to compensate for the interferences by performing a method of standard

additions (MSA). The MSA technique involves adding known amounts of standard to one or more aliquots of the sample digest. If MSA is performed, a different MSA curve must be generated for each sample. An MSA curve generated for a single sample must not be applied to other samples unless it can be clearly demonstrated that all samples exhibit the same matrix effect.

3.7 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

Prior to each field event, measures will be taken to test, inspect, and maintain all field equipment. All equipment used, including the differential GPS (DGPS) unit and digital camera will be tested for use before leaving for the field event.

The FC will be responsible for overseeing the testing, inspection, and maintenance of all field equipment. The laboratory PM will be responsible for ensuring that laboratory equipment testing, inspection, and maintenance requirements are met. The methods used in calibrating the analytical instrumentation are described in Section 3.7.

3.8 INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Multipoint initial calibrations will be performed on each instrument prior to sample analysis, after each major interruption to the analytical instrument, and when any more than one continuing calibration verification sample does not meet the specified criteria. The number of points used in the initial calibration is defined in each analytical method. Continuing calibration verifications will be performed daily for organic analyses, once every 10 samples for the inorganic analyses, and with every sample batch for conventional parameters to ensure proper instrument performance.

Gel permeation chromatography calibration verifications will be performed at least once every 7 days, and corresponding raw data will be submitted by the laboratory with the data package. In addition, florisil performance checks will be performed for every florisil lot, and the resulting raw data will be submitted with the data package, when applicable.

Calibration of analytical equipment used for chemical analyses includes instrument blanks or continuing calibration blanks, which provide information on the stability of the instrument's baseline. Continuing calibration blanks will be analyzed immediately after the continuing calibration verification at a frequency of one blank for every 10 samples analyzed for metals analyses and one blank for every 12 hrs for organic analyses. If the continuing calibration blank does not meet the specified criteria, the analysis must be discontinued. Analysis may resume after corrective actions have been taken to meet the method specifications. All project samples analyzed by an instrument found to be out of compliance must be reanalyzed. None of the field equipment requires calibration.

3.9 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

The field team leaders for each sampling event will have a checklist of supplies required for each day in the field (see Section 3.2.3). The FC will gather and check these supplies daily for satisfactory conditions before each field event. Batteries used in the DGPS unit and digital camera will be checked daily and recharged as necessary. Supplies and consumables for field sampling will be inspected upon delivery and accepted if the condition of the supplies is satisfactory. For example, jars will be inspected to ensure that they are the correct size and quantity and were not damaged in shipment.

3.10 DATA MANAGEMENT

All field data will be recorded on field forms (see Appendix B), which will be checked for missing information by the FC at the end of each field day and amended as necessary. After sampling is completed, all data from field forms will be entered into a Microsoft Excel® spreadsheet for import into the project database. A secondary QC check will be done to ensure that 100% of the data were properly transferred from the field forms to the spreadsheet. This spreadsheet will be kept on the Windward network drive, which is backed up daily. Field forms will be archived in the Windward library. All photographs will be transferred to the secure network or a CD each day.

Field sampling and analytical information (e.g., date of sample collection, anticipated number of samples, and test methods) will be submitted to the EPA's Analytical Services Tracking System (ANSETS) no later than the 15th of the month after sampling activities have occurred and the sampling compositing and analysis scheme have been approved. The project QA/QC coordinator will be responsible for the submitting the required information to ANSETS.

Analytical laboratories are expected to submit data in an electronic format as described in Section 2.5.2. The laboratory PM will contact the project QA/QC coordinator prior to data delivery to discuss specific format requirements.

A library of routines will be used to translate typical electronic output from laboratory analytical systems and to generate data analysis reports. The use of automated routines ensures that all data are consistently converted into the desired data structures and that operator time is kept to a minimum. In addition, routines and methods for quality checks will be used to ensure such translations are correctly applied.

Written documentation will be used to clarify how laboratory QA/QC samples were recorded in the data tables and to provide explanations of other issues that may arise. The data management task will include keeping accurate records of field and laboratory QA/QC samples so that project team members who use the data will have appropriate documentation. Data management files will be stored on a secure computer.

4 Assessment and Oversight

4.1 COMPLIANCE ASSESSMENTS AND RESPONSE ACTIONS

EPA or other management agencies may observe field activities during each sampling event, as needed. If situations arise where there is an inability to follow QAPP methods precisely, the Windward PM will determine the appropriate actions or consult EPA if the issue is significant.

4.1.1 Compliance assessments

Laboratory and field performance assessments consist of onsite EPA reviews of QA systems and equipment for sampling, calibration, and measurement. EPA personnel may conduct a laboratory audit prior to sample analysis. Any pertinent laboratory audit reports will be made available to the project QA/QC coordinator upon request. Analytical and taxonomy laboratories are required to have written procedures that address internal QA/QC; these procedures will be submitted for review by the project QA/QC coordinator upon request to ensure compliance with the QAPP. All laboratories and QA/QC coordinators are required to ensure that all personnel engaged in sampling and analysis tasks have appropriate training.

4.1.2 Response actions for field sampling

The FC, or a designee, will be responsible for correcting equipment malfunctions throughout field sampling and for resolving situations in the field that may result in nonconformance or noncompliance with the QAPP. All corrective measures will be immediately documented in the field logbook, and Protocol Modification Forms (Appendix B) will be completed.

4.1.3 Corrective action for laboratory analyses

Analytical laboratories are required to comply with their current written standard operating procedures, laboratory QA plan, and analytical methods. All laboratory personnel will be responsible for reporting problems that may compromise the quality of the data. The analysts will identify and correct any anomalies before continuing with sample analysis. The laboratory PMs will be responsible for ensuring that appropriate corrective actions are initiated as required for conformance with this QAPP.

The project QA/QC coordinator will be notified immediately if any QC parameter exceeds the project DQIs outlined in this QAPP (Table 3-10) and cannot be resolved through standard corrective action procedures. A description of the anomaly, the steps taken to identify and correct the anomaly, and the treatment of the relevant sample batch (i.e., recalculation, reanalysis, and re-extraction) will be submitted with the data package using the case narrative or corrective action form.

4.2 REPORTS TO MANAGEMENT

Progress reports for the EWG will be prepared by the FC following each sampling event. The project QA/QC coordinator will also prepare progress reports after the sampling is completed and samples have been submitted for analysis, when information is received from the laboratory, and when analyses are complete. The status of the samples and analyses will be indicated with emphasis on any deviations from the QAPP. A data report will be written after validated data are available for each sampling event, as described in Section 2.6.4.

5 Data Validation and Usability

5.1 DATA VALIDATION

The laboratory analyst is responsible for ensuring that the analytical data are correct and complete, that appropriate procedures have been followed, and that QC results are within the acceptable limits. The data validation process begins within the laboratory with the review and evaluation of data by supervisory personnel or QA specialists. The project QA/QC coordinator is responsible for ensuring that all analyses performed by the laboratories are correct, properly documented, and complete, and that they satisfy the project data quality objectives (DQOs) specified in this QAPP.

Data are not considered final until validated. Data validation will be conducted following EPA (1995; 2004; 1999; 2005; 1996) guidance. Independent third-party data review and summary validation of the analytical chemistry data will be conducted by EcoChem. A minimum of 20% of sample results or a single SDG will undergo full data validation. Full data validation parameters include:

- Quality control analysis frequencies
- Analysis holding times
- Laboratory blank contamination
- Instrument calibration
- Surrogate recoveries
- LCS recoveries
- MS recoveries
- MS/MSD RPDs
- Compound identifications
- Compound quantitations

- Instrument performance check (i.e., tune ion abundances)
- Internal standard areas and retention time shifts

If no discrepancies are found between reported results and raw data in the set that undergoes full data validation, then validation can proceed as a summary-level data validation on the rest of the data using all the QC forms submitted in the laboratory data package. QA review of the sediment and tissue chemistry data will be performed in accordance with the QA requirements of the project, the technical specifications of the analytical methods indicated in Tables 3-9, 3-10, and 3-11 and EPA guidance for organic and inorganic data review (EPA 1995; 2004; 1999; 2005; 1996). The EPA PM may have EPA peer review the third-party validation or perform data assessment/validation on a percentage of the data.

All discrepancies and requests for additional, corrected data will be discussed with the laboratories prior to issuing the formal data validation report. The project QA/QC coordinator should be informed of all contacts with the laboratories during data validation. The review procedures used and findings made during data validation will be documented on worksheets. The data validator will prepare a data validation report that will summarize QC results, qualifiers, and possible data limitations. Only validated data with appropriate qualifiers will be released for use in the EW supplemental remedial investigation/feasibility study. Rejected data will not be used for any purpose.

5.2 RECONCILIATION WITH DATA QUALITY OBJECTIVES

Data quality assessment will be conducted by the project QA/QC coordinator in consultation with EPA guidelines. The results of the third-party independent review and validation will be reviewed, and cases where the projects DQOs were not met will be identified. The usability of the data will be determined in terms of the magnitude of the DQO exceedance.

6 References

Anchor, King County. 2006. Fish collection data memorandum, scientific collection permit #06-402: Fish tissue sampling in the Lower Duwamish Waterway. Anchor Environmental, L.L.C. and King County Department of Natural Resources and Parks, Seattle, WA.

Anchor, Windward, Battelle, KPFF, Coast and Harbor Engineering. 2008. East Waterway Operable Unit supplemental remedial investigation/feasibility study: final conceptual site model and data gaps analysis report. Prepared for Port of Seattle. Anchor Environmental, L.L.C., Seattle, WA; Windward Environmental LLC, Seattle, WA; Battelle Memorial Institute, Seattle, WA; KPFF Consulting Engineers, Seattle, WA; and Coast and Harbor Engineering, Edmonds, WA.

Bane G, Robinson M. 1970. Studies on the shiner perch, *Cymatogaster aggregata* Gibbons, in upper Newport Bay, California. Wasmann J Biol 28(2):259-268.

EPA. 1995. EPA Region 10 SOP For the validation of Method 1668 toxic, dioxin-like, PCB data. Revision 1.0. Environmental Services Division, US Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 1996. EPA Region 10 SOP for the validation of polychlorinated dibenzodioxin (PCDD) and polychlorinated dibenzofuran (PCDF) data. Revision 2.0. Environmental Services Division, US Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 1999. USEPA contract laboratory program national functional guidelines for organic data review. EPA-540/R-99/008. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 2000a. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 1: Fish sampling and analysis, 3rd edition. EPA 823-B-00-007. Office of Water, US Environmental Protection Agency, Washington, DC.

EPA. 2000b. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 1: Fish sampling and analysis. Third ed. EPA 823-B-00-007. US Environmental Protection Agency, Washington, DC.

EPA. 2002. Guidance for quality assurance project plans. QA/G-5. EPA/240/R-02/009. Office of Environmental Information, US Environmental Protection Agency, Washington, DC.

EPA. 2004. USEPA contract laboratory program national functional guidelines for inorganic data review. EPA 540-R-04-004. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 2005. National functional guidelines for chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs) data review. OSWER 9240.1-51. EPA 540-R-05-001. Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency, Washington, DC.

EPA. 2007. ProUCL Version 4.0. Statistical software for environmental applications for data sets with and without nondetect observations [online]. Technical Support Center for Monitoring and Site Characterization, US Environmental Protection Agency. Updated 6/14/07. Available from: http://www.epa.gov/nerlesd1/tsc/software.htm.

Krone CA, Brown DW, Burrows DG, Chan SL, Varanasi U. 1989. Butyltins in sediment from marinas and waterways in Puget Sound Washington State, USA. Mar Pollut Bull 20:528-531.

Lassuy DR. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest). English sole. USFW biological report 82(11.101). Coastal Ecology Group, US Army Corps of Engineers, Vicksburg, MS and National Wetlands Research Center, US Fish and Wildlife Service, Slidell, LA.

Matthews KR. 1990. An experimental study of the habitat preferences and movement patterns of copper, quillback, and brown rockfishes (*Sebastes* spp.). Environ Biol Fish 29:161- 78.

NOAA. 1993. Tissue lipid determination method. In: Sampling and analytical methods of the National Status and Trends Program national benthic surveillance and mussel watch projects, 1984-1992. Vol 2: Comprehensive descriptions of complementary measurements. NOAA technical memorandum NOS ORCA 71. National Status and Trends Program, National Oceanic and Atmospheric Administration, Silver Spring, MD.

PSEP. 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Prepared for the Puget Sound Estuary Program. US Environmental Protection Agency, Region 10, Seattle, WA.

PSEP. 1997a. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final report. Prepared for the US Environmental Protection Agency, Seattle, WA. Puget Sound Water Quality Action Team, Olympia, WA.

PSEP. 1997b. Recommended quality assurance and quality control guidelines for the collection of environmental data in Puget Sound. Prepared for Puget Sound Estuary Program, US Environmental Protection Agency Region 10. Puget Sound Water Quality Action Team, Olympia, WA.

Singh A, Maichle R, Lee SE. 2006. On the computation of a 95% upper confidence limit of the unknown population mean based upon data sets with below detection

limit observations. Prepared for US Environmental Protection Agency. EPA/600/R-06/022. Lockheed Martin Environmental Services, Las Vegas, NV.

Stallard MO, Cola SY, Dooley CA. 1988. Optimization of butyltin measurements for seawater, tissue and marine sediment samples. Appl Organometal Chem 3:105-114.

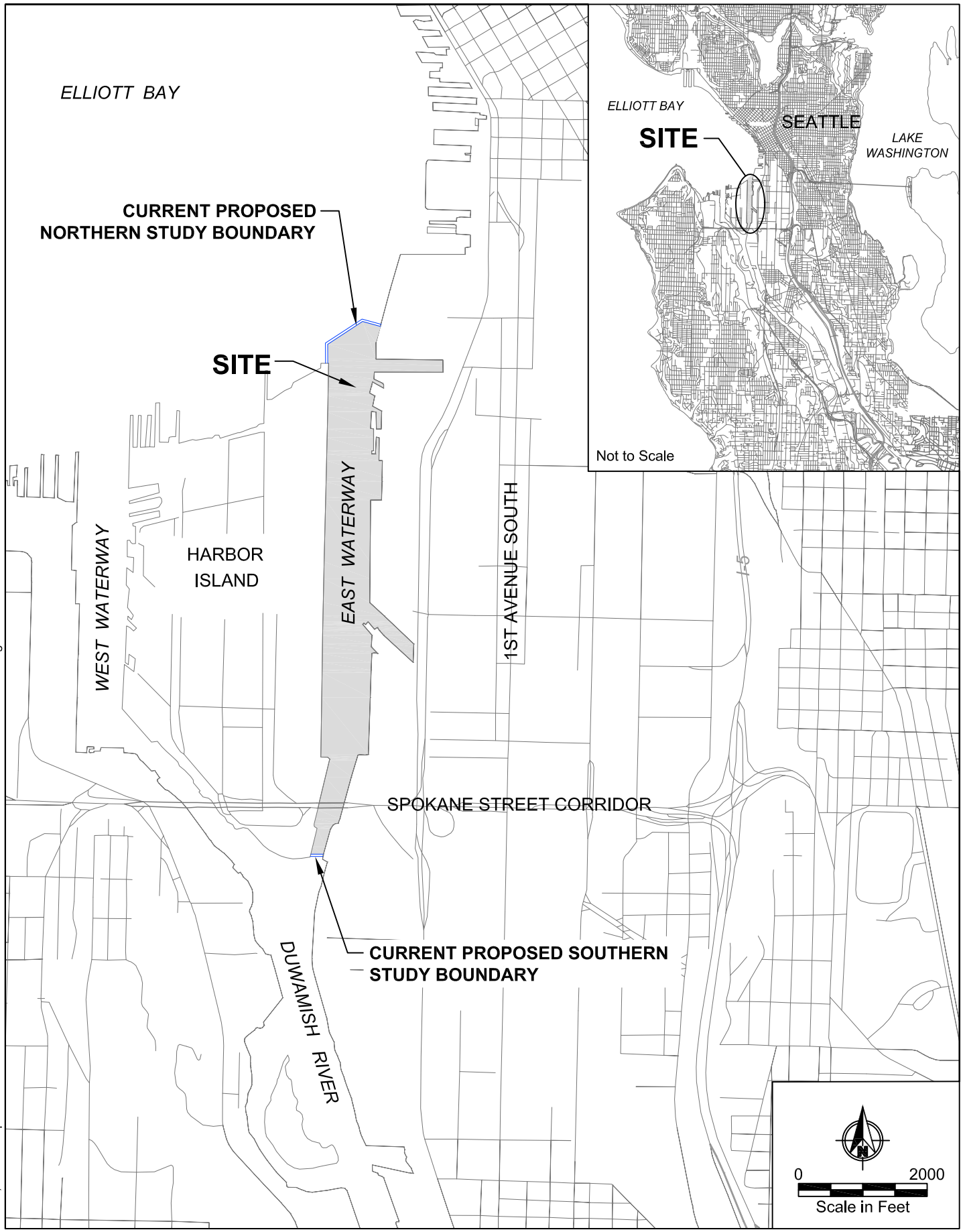
Stein D, Hassler TJ. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest): Brown rockfish, copper rockfish, and black rockfish. Bio. Rep. 82. Washington Department of Fish and Wildlife, Olympia, WA.

Windward. 2005. Lower Duwamish Waterway remedial investigation. Data report: Fish and crab tissue collection and chemical analyses. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2006a. East Waterway, Harbor Island Superfund site. Technical memorandum: tissue chemistry results for East Waterway fish tissue samples. Windward Environmental LLC, Seattle, WA.

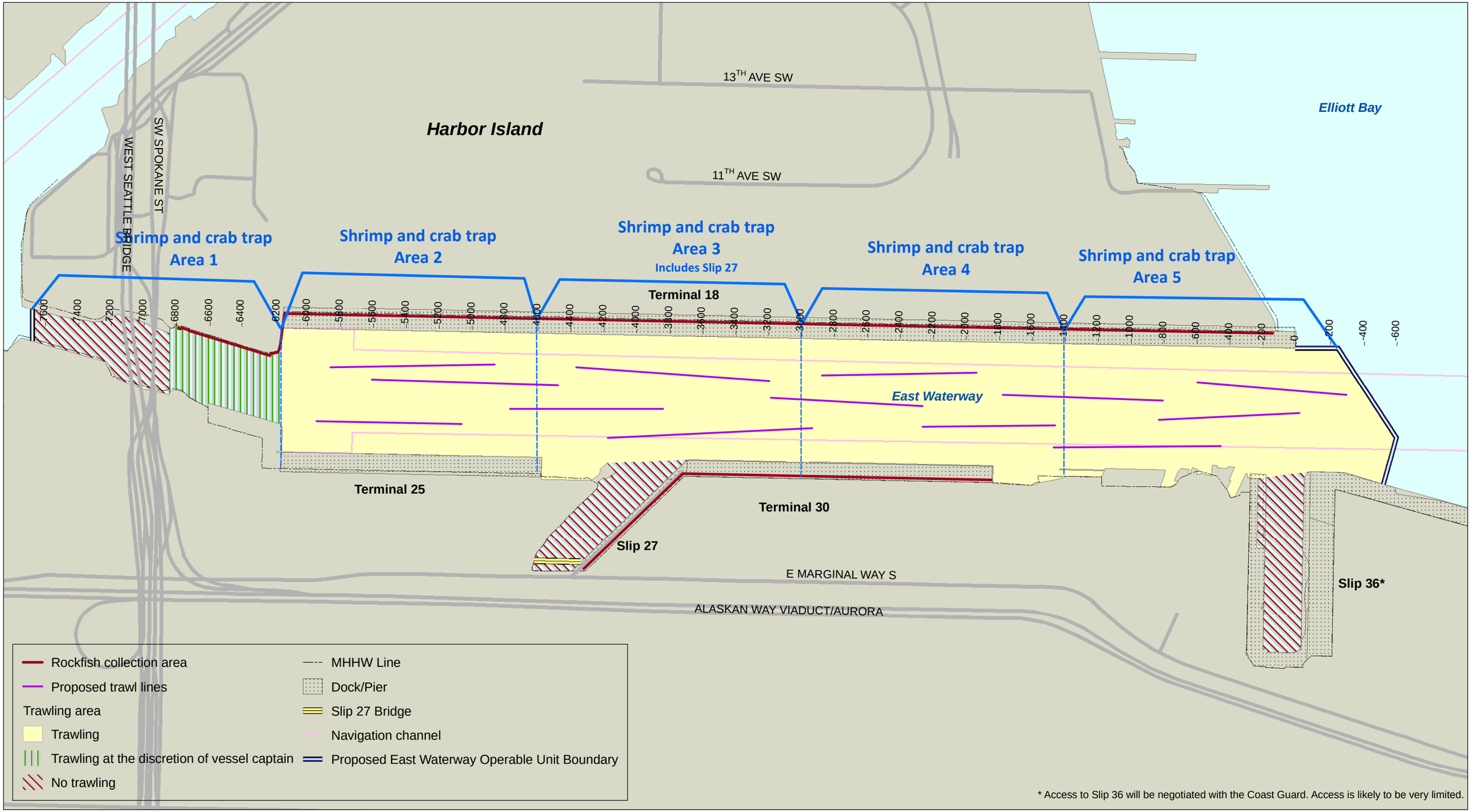
Windward. 2006b. Lower Duwamish Waterway remedial investigation. Data report: chemical analyses of fish and crab tissue samples collected in 2005. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

7 Maps



Jul 08, 2008 1:38pm cdavidson K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-040.dwg FIG 2-1

Map 2-1
Vicinity Map
East Waterway Operable Unit



Wind Ward LLC environmental

N

0 1,000 2,000 Feet

0 250 500 Meters

Map 3-1. Proposed fish and crab survey sampling areas

DRAFT

APPENDIX A

Health and Safety Plan

EAST WATERWAY OPERABLE UNIT
SUPPLEMENTAL REMEDIAL INVESTIGATION/ FEASIBILITY STUDY
DRAFT HEALTH AND SAFETY PLAN
FISH AND SHELLFISH TISSUE COLLECTION AND CHEMICAL ANALYSIS

For submittal to:

The US Environmental Protection Agency
Region 10
Seattle, WA

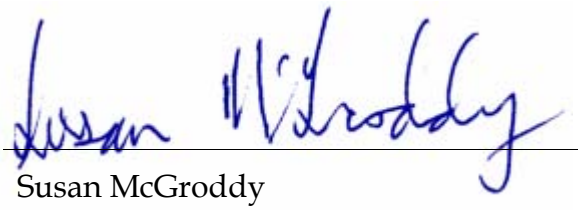
August 11, 2008

Prepared by:

Wind/Ward environmental LLC
200 West Mercer Street, Suite 401
Seattle, Washington • 98119

Health and Safety Plan

By their signature, the undersigned certify that this health and safety plan is approved and that it will be used to govern health and safety aspects of fieldwork described in the quality assurance project plan to which it is attached.



August 11, 2008

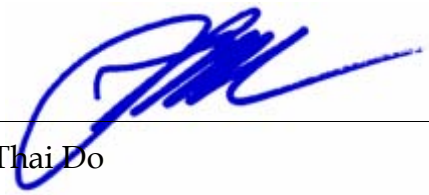
Susan McGroddy — Date

Project Manager

August 11, 2008

Tad Deshler — Date

Corporate Health and Safety Manager



August 11, 2008

Thai Do — Date

Field Coordinator/Health and Safety Officer

Table of Contents

List of Tables

Acronyms

CFR	Code of Federal Regulations
CPR	cardiopulmonary resuscitation
EW	East Waterway
FC	field coordinator
HAZWOPER	Hazardous Waste Operations and Emergency Response
HSM	health and safety manager
HSO	health and safety officer
HSP	health and safety plan
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PCBs	polychlorinated biphenyls
PEC	project emergency coordinator
PFD	personal flotation device
PM	project manager
PPE	personal protective equipment
QAPP	quality assurance project plan
TCDD	tetrachlorodibenzo-*p*-dioxin
USCG	US Coast Guard

1 Introduction

This site-specific health and safety plan (HSP) describes safe working practices for conducting field activities at potentially hazardous sites and for handling potentially hazardous materials/waste products. This HSP covers elements as specified in 29CFR1910§120. The goal of the HSP is to establish procedures for safe working practices for all field personnel.

This HSP addresses all activities associated with collection and handling of fish and shellfish in the East Waterway (EW). During site work, this HSP will be implemented by the field coordinator (FC), who is also the designated site health and safety officer (HSO), in cooperation with the corporate health and safety manager (HSM) and the project manager (PM).

All personnel involved in fieldwork on this project are required to comply with this HSP. The contents of this HSP reflect anticipation of the types of activities to be performed, knowledge of the physical characteristics of the site, and consideration of preliminary chemical data from previous investigations at the site. The HSP may be revised based on new information and/or changed conditions during site activities. Revisions will be documented in the project records.

2 Site Description and Project Scope

2.1 SITE DESCRIPTION

The sampling area is in the EW (see Map 2-1 in the quality assurance project plan [QAPP] to which this HSP is attached). The area is affected by tidal fluctuations. The QAPP provides complete details of the sampling program.

2.2 SCOPE AND DURATION OF WORK

This section summarizes the types of work that will be performed during field activities. Specific tasks to be performed are as follows:

- Collection of biological specimens from a boat using a high-rise trawl
- Collection of biological specimens from a boat using shrimp and crab traps
- Collection of biological specimens by scuba diving
- Collection of biological specimens by hand from a boat
- Sample handling, processing, and shipping

The collection of biological specimens is anticipated to occur in August and September 2008 as described in the QAPP.

3 Health and Safety Personnel

Key health and safety personnel and their responsibilities are described below. These individuals are responsible for the implementation of this HSP.

Project Manager: The PM has overall responsibility for the successful outcome of the project. The PM will ensure that adequate resources and budget are provided for the health and safety staff to carry out their responsibilities during fieldwork. The PM, in consultation with the HSM, makes final decisions concerning implementation of the HSP.

Field Coordinator/Health and Safety Officer: Because of the limited scope and duration of fieldwork, the FC and HSO will be the same person. The FC/HSO will direct field sampling activities, coordinate the technical components of the field program with health and safety components, and ensure that work is performed according to the QAPP. The FC/HSO will implement this HSP at the work location and will be responsible for all health and safety activities and the delegation of duties to a health and safety technician in the field, if appropriate. The FC/HSO also has stop-work authority, to be used if there is an imminent safety hazard or potentially dangerous situation. The FC/HSO or his designee shall be present during sampling and operations.

Corporate Health and Safety Manager: The HSM has overall responsibility for the preparation, approval, and revision of this HSP. The HSM will not necessarily be present during fieldwork but will be readily available, if required, for consultation regarding health and safety issues during fieldwork.

Field Crew and Dive Team: All field crew and dive team members must be familiar and comply with the information in this HSP. They also have the responsibility to immediately report any potentially unsafe or hazardous conditions to the FC/HSO. The dive team members must also adhere to practices in Research Support Services' dive plan (Attachment 1).

4 Hazard Evaluation and Control Measures

This section discusses potential physical and chemical hazards that may be associated with the proposed project activities and presents control measures for addressing these hazards. The activity hazard analysis (Section 4.4) lists the potential hazards associated with each site activity and the recommended site control to be used to minimize each potential hazard. Confined-space entry will not be necessary for this project. Therefore, hazards associated with this activity are not discussed in this HSP.

4.1 PHYSICAL HAZARDS

For this project, it is anticipated that physical hazards present a greater risk of injury than do chemical hazards. Physical hazards are identified and discussed below.

4.1.1 Slips, trips, and falls

As with all fieldwork sites, caution should be exercised to prevent slips on slick surfaces. In particular, sampling from a boat or other floating platform requires careful attention to minimize the risk of falling down or falling overboard. The same care should be used in rainy conditions or on the shoreline where slick rocks are found. Slips can be minimized through the use of boots with good treads, made of material that does not become overly slippery when wet.

Trips are always a hazard on the uneven deck of a boat, in a cluttered work area, or in the intertidal zone where uneven substrate is common. Personnel will keep work areas as free as possible from items that interfere with walking.

Falls can also be a hazard. Personnel can avoid falls by working as far from exposed edges as possible, erecting railings, and using fall protection when working on elevated platforms. For this project, no work that would present a fall hazard is anticipated.

4.1.2 Sampling equipment

A high-rise trawl and shrimp and crab traps will be used to collect tissue samples as described in Section 3.3 of the QAPP. Before sampling activities begin, all personnel will attend a training session to discuss the equipment that will be onboard the sampling vessel.

4.1.3 Falling overboard

Some of the sampling activities will be done from a boat. As with any work from a floating platform, there is a chance of falling overboard. Personal flotation devices (PFDs) will be worn by all personnel while working from the boat.

4.1.4 Manual lifting

Equipment and samples must be lifted and carried. Back strain can result if lifting is done improperly. During any manual handling tasks, personnel should lift with the load supported by their legs and not their backs. For heavy loads, an adequate number of people will be used, or if possible, a mechanical lifting/handling device will be used.

4.1.5 Heat stress, hypothermia, or frostbite

Sampling operations and conditions that might result in heat stress, hypothermia, or frostbite are not anticipated. Sampling will occur during the time of year when extreme weather conditions are not expected to occur.

4.1.6 Weather

In general, field team members will be equipped for the normal range of weather conditions. The FC/HSO will be aware of current weather conditions and of the potential for those conditions to pose a hazard to the field crew. Some conditions that might force work stoppage are electrical storms, high winds, or high waves resulting from winds.

4.1.7 Sharp objects

Sampling operations might result in the exposure of field personnel to sharp objects on top of or buried within the sediment. If these objects are encountered, field personnel should not touch them. Also, field personnel should not dig in the sediment by hand.

4.1.8 Scuba diving

Scuba diving presents an array of risks not common at a normal worksite. Therefore, tasks that involve diving will be performed by a professional diver who has been properly trained and certified and is aware of the myriad inherent risks involved with scuba diving in hazardous environments. With proper training, the risk of these potential hazards can be minimized. Commercial divers provided by Research Support Services will adhere to their dive plan (Attachment 1).

The diver will dive line-tended, with wireless communication to the surface. A safety diver will tend the line and wear a headset to talk with the diver in the water. The safety diver will also be suited up and ready to don gear if necessary. In the unlikely event that the in-water diver would require assistance, the diver could be retrieved using the tending line or assisted by the safety diver. Emergency oxygen and first aid will be on the boat, as well as a dive plan that will list local hospitals and dive-related emergency contact information (Attachment 1).

Equipment failure is always a concern. Divers should be familiar with their specific type of equipment and check the tank, regulator, buoyancy control device, gauges, and any other equipment to make sure everything is in proper working order prior to use. The compressed air supply is filled by a local dive store so an air check is not necessary. The diver is also equipped with a pony bottle, which is a small emergency (bailout) air tank.

Divers must be careful to avoid pilings and other obstacles that might snag gear or entrap the diver. Having a clear sense of the layout of the area before getting in the water and taking extra caution during times of low visibility will minimize the risk from these hazards.

Hypothermia sets in much more quickly in water than in air. Wearing proper insulation and knowing the symptoms can help prevent this hazard. Warm clothes should be available on board the support boat.

Nitrogen narcosis is a risk associated with spending too much time at depth. This project will not require diving below approximately 50 ft, so the risk of narcosis is minimal. However, it is still necessary to consult dive tables to create a dive profile for each dive. Strict adherence to the dive plan should prevent nitrogen narcosis.

If boat traffic is a possibility, a dive flag must be deployed in the vicinity of the divers. Divers should surface as close as possible to the flag and/or support boat. Diving will not be done in the channel where shipping activity takes place. The dive tender will continuously monitor Channels 13, 14, and 16 for boat traffic near the dive area, advise other vessels of diving operations and, if possible, warn off boat traffic that may pose a hazard to divers.

4.2 VESSEL HAZARDS

Because of the high volumes of vessel and barge traffic on the EW, precautions and safe boating practices will be implemented to ensure that the field boat does not interrupt vessel traffic. Additional potential vessel emergency hazards and responses are listed in Table 1.

Table 1. Potential vessel emergency hazards and responses

POTENTIAL EMERGENCY OR HAZARD	RESPONSE
Fire or explosion	If manageable, personnel should attempt to put out a small fire with a fire extinguisher. Otherwise, personnel should call the USCG or 911 and evacuate the area (by rescue boat or swimming) and meet at a designated area. The FC/HSO will take roll call to make sure everyone evacuated safely. Emergency meeting places will be determined in the field during the daily safety briefing.
Medical emergency or injury	At least one person with current first aid and CPR training will be aboard the vessel at all times. This person will attempt to assess the nature and severity of the injury, immediately call 911, and perform CPR if necessary. Personnel should stop work and wait for medical personnel to arrive. Once the emergency has passed, the FC/HSO should fill out a site accident report.
Person overboard	All personnel aboard the sampling vessel will wear PFDs at all times. One person should keep an eye on the individual who fell overboard and shout the distance (boat lengths) and direction (o'clock) of the individual from the vessel. Personnel should stop work and use the vessel to retrieve the individual in the water.
Sinking vessel	Personnel should call the USCG immediately. If possible, personnel should wait for a rescue boat to arrive to evacuate vessel personnel. See fire or explosion (above) for emergency evacuation procedures. The FC/HSO will take a roll call to make sure everyone is present.
Lack of visibility	If navigation visibility or personal safety is compromised because of smoke, fog, or other unanticipated hazards, personnel should stop work immediately. The vessel operator and FC/HSO will assess the hazard and, if necessary, send out periodic horn blasts to mark vessel location to other vessels potentially in the area, move to a secure location (i.e., berth), and wait for the visibility to clear.
Loss of power	Personnel should stop work and call the USCG for assistance. Personnel should use oars to move vessel towards the shoreline. Other vessel personnel should watch for potential collision hazards and notify the vessel operator if hazards exist. Personnel should secure the vessel to a berth, dock, or mooring as soon as possible.

POTENTIAL EMERGENCY OR HAZARD	RESPONSE
Collision	Personnel should stop work and call the USCG for assistance. The FC/HSO and vessel operator will assess damage and potential hazards. If necessary, the vessel will be evacuated and secured until repairs can be made.

CPR – cardiopulmonary resuscitation
FC – field coordinator
HSO – health and safety officer
PFD – personal flotation device
USCG – US Coast Guard

4.3 CHEMICAL HAZARDS

Previous investigations have shown that some chemical substances are present at higher-than-background concentrations in the sampling area. For the purpose of discussing potential exposure to substances in sediments, the chemicals of concern are metals, tributyltin, dioxins and furans, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).

4.3.1 Exposure routes

Potential routes of chemical exposure include inhalation, dermal contact, and ingestion. Exposure will be minimized by using safe work practices and by wearing the appropriate personal protective equipment (PPE). Further discussion of PPE requirements is presented in Section 7.

Inhalation —Inhalation is not expected to be an important route of exposure for this project.

Dermal exposure — Dermal exposure to hazardous substances associated with sediments, surface water, or equipment decontamination will be controlled through the use of PPE and by adherence to detailed sampling and decontamination procedures.

Ingestion — Ingestion is not considered a major route of exposure for this project. Accidental ingestion of surface water is possible. However, careful handling of equipment and containers aboard the boat should prevent the occurrence of water splashing or spilling during sample collection and handling activities.

4.3.2 Description of chemical hazards

Metals and tributyltin — Exposure to metals may occur via ingestion or skin contact. As mentioned above, neither is likely as an exposure route. Metal fumes or metal-contaminated dust will not be encountered during field and sample handling activities. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for the passage of any of the metals into the body. Field procedures require immediate washing of sediments from exposed skin.

Polycyclic aromatic hydrocarbons — Exposure to PAHs may occur via ingestion or skin contact. The most important human health exposure pathway for this group of chemicals, inhalation, is not expected to occur at this site. Animal studies have shown that PAHs can cause harmful effects on skin, body fluids, and the ability to fight disease after both short- and long-term exposure, but these effects have not been documented in people. Some PAHs may reasonably be expected to be carcinogens. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for passage of any of the compounds into the body. Field procedures require immediate washing of sediments from exposed skin.

Polychlorinated biphenyls — Prolonged skin contact with PCBs may cause acne-like symptoms known as chloracne. Irritation to eyes, nose, and throat may also occur. Acute and chronic exposure can damage the liver, and cause symptoms of edema, jaundice, anorexia, nausea, abdominal pains, and fatigue. PCBs are a suspected human carcinogen. Skin absorption may substantially contribute to the uptake of PCBs. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for the passage of any of these compounds into the body. Field procedures require the immediate washing of sediments from exposed skin.

Dioxins/furans — Prolonged skin contact with dioxins/furans may cause acne-like symptoms known as chloracne. Other effects to the skin, such as red skin rashes, have been reported to occur in people following exposure to high concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). Acute and chronic exposure can damage the liver, result in an increase in the risk of diabetes and abnormal glucose tolerance, and may increase the risk for reproductive and developmental effects. 2,3,7,8-TCDD is a possible human carcinogen, and a mixture of dioxins/furans with six chlorine atoms (four of the six chlorine atoms at the 2, 3, 7, and 8 positions) is a probable human carcinogen. Skin absorption may substantially contribute to the uptake of dioxins/furans. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for the passage of any of the compounds into the body. Field procedures require the immediate washing of sediments from exposed skin.

4.4 ACTIVITY HAZARD ANALYSIS

The activity hazard analysis summarizes the field activities to be performed during the project, outlines the hazards associated with each activity, and presents controls that can reduce or eliminate the risk of the hazard occurring.

Table 2 presents the activity hazard analysis for the following activities:

- Sampling from a boat
- Scuba diving

Table 2. Activity hazard analysis

ACTIVITY	HAZARD	CONTROL
Sampling from a boat	falling overboard	Use care in boarding and departing from vessel. Wear a PFD.
	skin contact with contaminated sediments or liquids	Wear modified Level D PPE.
	back strain	Use appropriate lifting technique when transporting equipment and supplies to/from the boat, or seek help.
Scuba diving	loss of communication	Terminate the dive.
	equipment failure	Pre-dive check out, diver tender and/or safety diver present.
	scrapes, bruises, and entrapment by pilings and other obstacles	Be familiar with the area before entering the water. Exercise caution when visibility is low.
	hypothermia	Wear appropriate insulation. Be aware of the symptoms and have warm clothes available.
	nitrogen narcosis	Consult dive tables prior to each dive.
	boat traffic	Deploy the dive flag in the vicinity of the divers. Ascend carefully and as close as possible to the support boat. Have dive tender continuously monitor Channels 13, 14, and 16 for boat traffic near dive area. Ensure that dive tender advises other vessels of diving operations and warn off boat traffic that may pose a hazard to the divers.

PFD – personal flotation device
PPE – personal protective equipment

5 Work Zones and Shipboard Access Control

During sampling and sample handling activities, work zones will be established to identify where sample collection and processing are actively occurring. The intent of the zone is to limit the migration of sample material out of the zone and to restrict access to active work areas by defining work zone boundaries.

5.1 WORK ZONE

The work zone will encompass the area where sample collection and handling activities are performed. The FC/HSO will delineate the work zone as a particular area on-board the collection vessels. Only persons with appropriate training, PPE, and authorization from the FC/HSO will be allowed to enter the work zone while work is in progress.

5.2 DECONTAMINATION STATION

A decontamination station will be set up, and personnel will clean soiled boots or PPE prior to leaving the work zone. The station will have the buckets, brushes, soapy water, rinse water, or wipes necessary to clean boots, PPE, or other equipment leaving the work zones. Plastic bags will be provided for expendable and disposable

materials. If the location does not allow for the establishment of a decontamination station, the FC/HSO will provide alternatives to prevent the spread of contamination.

Decontamination of the boat will also be completed at the end of each work day. Cockpit and crew areas will be rinsed down with site water to minimize the accumulation of sediment.

5.3 ACCESS CONTROL

Boat security and access control will be the responsibility of the FC/HSO and boat captain. Boat access will be granted only to essential project personnel and authorized visitors. Any security or access control problems will be reported to the PM or appropriate authorities.

6 Safe Work Practices

Following common sense rules will minimize the risk of exposure or accidents at the work site. These general safety rules will be followed onsite:

- Do not climb over or under obstacles of questionable stability.
- Do not eat, drink, smoke, or perform other hand-to-mouth transfers in the work zone.
- Work only in well-lighted spaces.
- Never enter a confined space without the proper training, permits, and equipment.
- Make eye contact with equipment operators when moving within the range of their equipment.
- Be aware of the movements of shipboard equipment when not in the operator's range of vision.
- Get immediate first aid for all cuts, scratches, abrasions, or other minor injuries.
- Use the established sampling and decontamination procedures.
- Always use the buddy system.
- Be alert to your own and other workers' physical condition.
- Report all accidents, no matter how minor, to the FC/HSO.
- Do not do anything dangerous or unwise even if ordered by a supervisor.

7 Personal Protective Equipment and Safety Equipment

Appropriate PPE will be worn as protection against potential hazards. In addition, a PFD will be required for all personnel when working aboard the boat. Prior to donning PPE, the field crew will inspect their PPE for any defects that might render the equipment ineffective.

Fieldwork will be conducted in Level D or modified Level D PPE, as discussed in Sections 7.1 and 7.2. Situations that would require PPE beyond modified Level D are not anticipated. Should the FC/HSO determine that PPE beyond modified Level D is necessary, the HSM will be notified and an alternative PPE selected.

7.1 Level D Personal Protective Equipment

Individuals performing general activities in which skin contact with contaminated materials is unlikely will wear Level D PPE. Level D PPE includes the following:

- Cotton overalls or lab coats
- Chemical-resistant steel-toed boots
- Chemical-resistant gloves
- Safety glasses

7.2 Modified Level D Personal Protective Equipment

Individuals performing activities in which skin contact with contaminated materials is possible but inhalation risks are not expected will be required to wear an impermeable outer suit. The type of outerwear will be chosen according to the types of chemical contaminants that might be encountered. Modified Level D PPE includes the following:

- Impermeable outer garb, such as rain gear
- Chemical-resistant steel-toed boots
- Chemical-resistant outer gloves

7.3 Safety Equipment

In addition to the above-identified PPE, basic emergency and first aid equipment will also be provided. Equipment for the field team will include:

- A copy of this HSP
- First aid kit adequate for the number of personnel in the field crew
- Emergency eyewash

The FC/HSO will ensure that the safety equipment is available. Equipment will be checked daily to ensure its readiness for use.

8 Monitoring Procedures for Site Activities

A monitoring program that addresses the potential site hazards will be implemented. For this project, air, dust, and noise monitoring will not be necessary. No volatile organic compounds have been identified among the expected contaminants, the sampled media will be wet and will not pose a dust hazard, and none of the equipment emits high-amplitude (i.e., > 85 dBA) noise. For this project, the monitoring program will consist of all individuals monitoring themselves and their co-workers for signs of potential physical stress or illness.

All personnel will be instructed to look for and inform each other of any deleterious changes in their physical or mental conditions during the performance of all field activities. Examples of such changes are as follows:

- Headaches
- Dizziness
- Nausea
- Symptoms of heat stress
- Blurred vision
- Cramps
- Irritation of eyes, skin, or respiratory system
- Changes in complexion or skin color
- Changes in apparent motor coordination
- Increased frequency of minor mistakes
- Excessive salivation or changes in papillary response
- Changes in speech ability or speech pattern
- Shivering
- Blue lips or fingernails

If any of these conditions develop, work will be halted immediately and the affected person(s) evaluated. If further assistance is needed, personnel at the local hospital will be notified, and an ambulance will be summoned if the condition is thought to be serious. If the condition is the direct result of sample collection or handling activities, procedures will be modified to address the problem.

9 Decontamination

Decontamination is necessary to prevent the migration of contaminants from the work zone(s) into the surrounding environment and to minimize the risk of exposure of personnel to contaminated materials that might adhere to PPE. The following

sections discuss personnel and equipment decontamination. The following supplies will be available to perform decontamination activities:

- Wash buckets
- Rinse buckets
- Long-handled scrub brushes
- Clean water sprayers
- Paper towels
- Plastic garbage bags
- Alconox® or similar decontamination solution

9.1 MINIMIZATION OF CONTAMINATION

The first step in addressing contamination is to prevent or minimize exposure to existing contaminated materials and the spread of those materials. During field activities, the FC/HSO will enforce the following measures:

Personnel:

- Do not walk through areas of obvious or known contamination.
- Do not handle, touch, or smell contaminated materials directly.
- Make sure PPE has no cuts or tears prior to use.
- Fasten all closures on outer clothing, covering with tape if necessary.
- Protect and cover any skin injuries.
- Stay upwind of airborne dusts and vapors.
- Do not eat, drink, chew tobacco, or smoke in the work zones.

Sampling equipment and boat:

- Place clean equipment on a plastic sheet or aluminum foil to avoid direct contact with contaminated media.
- Keep contaminated equipment and tools separate from clean equipment and tools.
- Clean boots before enter.ing the boat.

9.2 PERSONNEL DECONTAMINATION

The FC/HSO will ensure that all site personnel are familiar with personal decontamination procedures. Personnel will perform decontamination procedures, as appropriate, before eating lunch, taking a break, or leaving the work location. Decontamination procedures for field personnel include:

1. Rinse off the outer suit if it is heavily soiled.

2. Wash and rinse outer gloves and boots with water.
3. Remove and inspect outer gloves and discard them if damaged.
4. Wash hands if taking a break.
5. Don necessary PPE before returning to work.
6. Dispose of soiled, disposable PPE before leaving for the day.

In addition to the decontamination procedures listed above, divers will:

1. Thoroughly rinse dive suit and gear after each dive.
2. Inspect gear for mud or stains, and re-rinse or scrub with Alconox®, if necessary.
3. Discard any damaged or heavily soiled gear after the project, if necessary.
4. Launder dry suit underwear after the project.

9.3 SAMPLING EQUIPMENT DECONTAMINATION

Sampling equipment will be decontaminated to minimize sample contamination. The practices listed below will be followed:

- Caught fish will be placed only on clean surfaces, such as aluminum foil (dull side touching the fish).
- Ice chests will be scrubbed with Alconox® detergent and rinsed with deionized water prior to any sampling activities.
- Samples will be placed in resealable, waterproof plastic bags to avoid contamination from melting ice.
- Sampling equipment will be free from contaminants such as oils, grease, and fuels.
- All utensils or equipment used directly in handling fish (e.g., such as measuring boards) will be scrubbed with Alconox® detergent and rinsed with deionized water, and stored in aluminum foil until use.

9.4 VESSEL DECONTAMINATION

Some sampling will be conducted from a boat. Care will be taken to minimize the amount of sediment spilled on the vessel. The vessel deck will be hosed off regularly to remove sediment from the cockpit and crew areas to minimize slipping hazards and sediment transport on boots through work zones.

10 Disposal of Contaminated Materials

Contaminated materials that may be generated during field activities include PPE, decontamination fluids, and excess sample material. These contaminated materials will be disposed of as an integral part of the project.

10.1 PERSONAL PROTECTIVE EQUIPMENT

Gross surface contamination will be removed from PPE. All disposable sampling materials and PPE, such as disposable coveralls, gloves, and paper towels used in sample processing, will be placed in heavyweight garbage bags. Filled garbage bags will be placed in a normal refuse container for disposal as solid waste.

10.2 EXCESS SAMPLE MATERIALS

At each sampling location, all excess or unwanted specimens and sediment will be returned to the site.

11 Training Requirements

Individuals performing work at locations where potentially hazardous materials and conditions may be encountered must meet specific training requirements. It is not anticipated that hazardous concentrations of contaminants will be encountered in sampled material, so training will consist of site-specific instruction for all personnel and the oversight of inexperienced personnel by an experienced person for one working day. The following sections describe the training requirements for this fieldwork.

11.1 PROJECT-SPECIFIC TRAINING

In addition to Hazardous Waste Operations and Emergency Response (HAZWOPER) training, as described in Section 2.4 of the QAPP, field personnel will undergo training specifically for this project. All personnel must read this HSP and be familiar with its contents before beginning work. Personnel will acknowledge reading the HSP by signing the Field Team Health and Safety Plan Review Form (Attachment 2). The completed form will be kept in the project files.

Boat operators will also be required to have the US Coast Guard (USCG) auxiliary boating safely certification. The boat captain and FC/HSO or a designee will provide project-specific training prior to the first day of fieldwork and whenever new workers arrive. Field personnel will not be allowed to begin work until project-specific training has been completed and documented by the FC/HSO. Training will address the HSP and all health and safety issues and procedures pertinent to field operations. Training will include, but not be limited to, the following topics:

- Activities with the potential for chemical exposure

- Activities that pose physical hazards and actions to control the hazard
- Ship access control and procedure
- Use and limitations of PPE
- Decontamination procedures
- Emergency procedures
- Use and hazards of sampling equipment
- Location of emergency equipment
- Vessel safety practices
- Emergency evacuation and emergency procedures

11.2 DAILY SAFETY BRIEFINGS

The FC/HSO or a designee and the boat captain will present safety briefings before the start of each day's activities. These safety briefings will outline the activities expected for the day, update work practices and hazards, address any specific concerns associated with the work location, and review emergency procedures and routes. The FC/HSO or designee will document safety briefings in the logbook.

11.3 FIRST AID AND CPR

At least one member of the field team must have first-aid and cardiopulmonary resuscitation (CPR) training. The diver and dive tender will also be trained in first aid and CPR as required by the Research Support Services' dive plan. Documentation of which individuals possess first-aid and CPR training will be kept in the project health and safety files.

12 Medical Surveillance

A medical surveillance program conforming to the provisions of 29CFR1910§120(f) will not be necessary for field team members because the field team members do not meet any of the four criteria outlined in the regulations for the implementation of a medical surveillance program:

- Employees who are or may be exposed to hazardous substances or health hazards at or above permissible exposure levels for 30 days or more per year (1910.120(f)(2)(I)
- Employees who must wear a respirator for 30 days or more per year (1910.120(f)(2)(ii))
- Employees who are injured or become ill due to possible overexposures involving hazardous substances or health hazards from an emergency response or hazardous waste operation (1910.120(f)(2)(iii))

- Employees who are members of HAZMAT teams (1910.120(f)(2)(iv)).

As described in Section 8, employees will monitor themselves and each other of any deleterious changes in their physical or mental condition during the performance of all field activities.

13 Reporting and Record Keeping

Each member of the field crew will sign the Field Team Health and Safety Plan Review (see Attachment 2). If necessary, accident/incident report forms and Occupational Safety and Health Administration (OSHA) Form 200s will be completed by the FC/HSO.

The FC/HSO or a designee will maintain a health and safety field logbook that records health- and safety-related details of the project. Alternatively, entries may be made in the field logbook, in which case a separate health and safety logbook will not be required. The logbook must be bound, and the pages must be numbered consecutively. Entries will be made with indelible blue ink. At a minimum, each day's entries must include the following information:

- Project name or location
- Names of all personnel
- Weather conditions
- Type of fieldwork being performed

The individual maintaining the entries will initial and date the bottom of each completed page. Blank space at the bottom of an incompletely filled page will be lined out. Each day's entries will begin on the first blank page after the previous workday's entries.

14 Emergency Response Plan

As a result of the hazards and the conditions under which operations will be conducted, the potential exists for an emergency situation to occur. Emergencies may include personal injury, exposure to hazardous substances, fire, explosion, or the release of toxic or non-toxic substances (i.e., spills). OSHA regulations require that an emergency response plan be available to guide actions in emergency situations.

Onshore organizations will be relied upon to provide response in emergency situations. The local fire department and ambulance service can provide timely response. Field personnel will be responsible for identifying emergency situations, providing first aid if applicable, notifying the appropriate personnel or agency, and evacuating any hazardous area. Shipboard personnel will attempt to control only very minor hazards that could present an emergency situation, such as a small fire, and will otherwise rely on outside emergency response resources.

The following sections identify the individual(s) who should be notified in case of emergency, provide a list of emergency telephone numbers, offer guidance for particular types of emergencies, and provide directions for getting from any sampling location to a hospital.

14.1 PRE-EMERGENCY PREPARATION

Before the start of field activities, the FC/HSO will ensure that preparation has been made in anticipation of emergencies. This preparation includes the following:

- Meeting with the FC/HSO and equipment handlers concerning the emergency procedures to be followed in the event of an injury
- Conducting a training session informing all field personnel of emergency procedures, locations of emergency equipment and their use, and proper evacuation procedures
- Conducting a training session (led by senior staff responsible for operating field equipment) to apprise field personnel of operating procedures and specific risks associated with field equipment
- Ensuring that field personnel are aware of the existence of the emergency response plan in the HSP and ensuring that a copy of the HSP accompanies the field team

14.2 PROJECT EMERGENCY COORDINATOR

The FC/HSO will serve as the project emergency coordinator (PEC) in the event of an emergency. He will designate a replacement for times when he is not available or is not serving as the PEC. The designation will be noted in the logbook. The PEC will be notified immediately when an emergency is recognized. The PEC will be responsible for evaluating the emergency situation, notifying the appropriate emergency response units, coordinating access with those units, and directing onboard interim actions before the arrival of emergency response units. The PEC will notify the HSM and the PM as soon as possible after initiating an emergency response action. The PM will have responsibility for notifying the client.

14.3 EMERGENCY RESPONSE CONTACTS

All personnel must know whom to notify in the event of an emergency situation, even though the FC/HSO has primary responsibility for notification. Table 3 lists the names and phone numbers for emergency response services and individuals.

Table 3. Emergency response contacts

CONTACT	TELEPHONE NUMBER
Emergency Numbers	
Ambulance	911
Police	911
Fire	911
Harborview Medical Center	(206) 323-3074
US Coast Guard Office Emergency General information	 (206) 286-5400 (206) 442-5295 UHF Channel 16
National Response Center	(800) 424-8802
US Environmental Protection Agency	(908) 321-6660
Washington State Department of Ecology – Northwest Region Spill Response (24-hour emergency line)	(206) 649-7000
Emergency Contacts	
Susan McGroddy, Project Manager	(206) 812-5421
Tad Deshler, Corporate Health and Safety Manager	(206) 812-5406
Thai Do, Field Coordinator/ Health and Safety Officer	(206) 353-9346 (site cellular telephone)

14.4 RECOGNITION OF EMERGENCY SITUATIONS

Emergency situations will generally be recognizable by observation. An injury or illness will be considered an emergency if it requires treatment by a medical professional and cannot be treated with simple first-aid techniques.

14.5 DECONTAMINATION

In the case of evacuation, decontamination procedures will be performed only if doing so does not further jeopardize the welfare of site workers. If an injured individual is also heavily contaminated and must be transported by emergency vehicle, the emergency response team will be informed of the type of contamination. To the extent possible, contaminated PPE will be removed but only if doing so does not exacerbate the injury. Plastic sheeting will be used to reduce the potential for spreading contamination to the inside of the emergency vehicle.

14.6 FIRE

Field personnel will attempt to control only small fires. If an explosion appears likely, personnel will follow evacuation procedures specified during the training session. If a fire cannot be controlled with the onboard fire extinguisher that is part of the required safety equipment, personnel will either withdraw from the vicinity of the fire or evacuate the boat as specified in the training session.

14.7 PERSONAL INJURY

In the event of serious personal injury, including unconsciousness, possibility of broken bones, severe bleeding or blood loss, burns, shock, or trauma, the first responder will immediately do the following:

- Administer first aid, if qualified.
- If not qualified, seek out an individual who is qualified to administer first aid, if time and conditions permit.
- Notify the PEC of the incident, the name of the individual, the location, and the nature of the injury.

The PEC will immediately do the following:

- Notify the boat captain and FC/HSO, and the appropriate emergency response organization.
- Assist the injured individual(s).
- Follow the emergency procedures for retrieving or disposing of equipment and leave the site and proceed to the predetermined land-based emergency pick-up.
- Designate someone to accompany the injured individual to the hospital.
- If a life-threatening emergency occurs (i.e., injury in which death is imminent without immediate treatment), the FC/HSO or boat captain will call 911 and arrange to meet the emergency responder at the nearest accessible location or dock. For injuries or emergencies that are not life-threatening (i.e., broken bones, minor lacerations), the PEC will follow the procedures outlined above and proceed to the Harbor Island Marina or to an alternative location if that would be more expedient.
- Notify the HSM and the PM.

If the PEC determines that emergency response is not necessary, he or she may direct someone to decontaminate and transport the individual by vehicle to the nearest hospital. Directions describing the route to the hospital are in Section 14.10.

If a worker leaves the to seek medical attention, another worker should accompany that person to the hospital. When in doubt about the severity of an injury or exposure, always seek medical attention as a conservative approach and notify the PEC.

The PEC will be responsible for completing all accident/incident field reports, OSHA Form 200s, and other required follow-up forms.

14.8 OVERT PERSONAL EXPOSURE OR INJURY

If an overt exposure to toxic materials occurs, the first responder to the victim will initiate actions to address the situation. The following actions should be taken, depending on the type of exposure.

14.8.1 Skin contact

- Wash/rinse the affected area thoroughly with copious amounts of soap and water.
- If eye contact has occurred, eyes should be rinsed for at least 15 minutes using the eyewash that is part of the onboard emergency equipment.
- After initial response actions have been taken, seek appropriate medical attention.

14.8.2 Inhalation

- Move victim to fresh air.
- Seek appropriate medical attention.

14.8.3 Ingestion

- Seek appropriate medical attention.

14.8.4 Puncture wound or laceration

- Seek appropriate medical attention.

14.9 SPILLS AND SPILL CONTAINMENT

No bulk chemicals or other materials subject to spillage are expected to be used during this project. Accordingly, no spill containment procedure is required for this project.

14.10 EMERGENCY ROUTE TO THE HOSPITAL

The name, address, and telephone number of the hospital that will be used to provide medical care is as follows:

Harborview Medical Center
325 Ninth Avenue
Seattle, WA
(206) 323-3074

Directions from the vicinity of EW to Harborview Medical Center are as follows:

- Dock the vessel at the First Avenue S boat launch.
- Drive east on S River Street.

- Turn left on Occidental Avenue S.
- Turn left on E Marginal Way S.
- Turn right on S Michigan Street.
- Look for entrance ramps to I-5 northbound.
- Head north on I-5.
- Take the James Street exit.
- Head east on James Street to Ninth Avenue.
- Turn right on Ninth Avenue.
- Emergency entrance will be two blocks south on the right.

15 References

PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final Report. Prepared for the U.S. Environmental Protection Agency, Seattle, Washington, and the Puget Sound Water Quality Action Team, Olympia, WA.

Attachment 1. Dive Plan

RSS RESEARCH SUPPORT SERVICES, INC. 206-550-5202
8010 NE Lovgren Road. Bainbridge Island, WA 98110 eparker@rssincorporated.com

DIVE SAFETY AND WORK PLAN
East Waterway Rockfish Collection and Clam Survey
for
Windward Environmental

EMERGENCY RESPONSE INFORMATION

NOTE: Call local 911 first in case of any medical emergency prior to traveling to the emergency medical facility. Call DAN with questions regarding treatment of diving emergencies.

Telephone emergency: 911 and DAN 1-919-684-8111

Coast Guard emergency: 1-206-217-6000 (*CG from any cell phone)

Dive Emergency Gear: First aid kit, emergency oxygen kit, VHF radio, and cellular phones

Field Cellular Phone: 206-550-5202 Eric Parker

Nearest Dive Emergency Medical Facilities:

Harborview Medical Center, 325 9th Ave., Seattle (206) 731-3074 emergency room

Virginia Mason Hospital, Hyperbaric Medicine Dept., 1202 Terry Ave., Seattle

(206) 583-6543 hyperbaric; (206) 583-6433 emergency room and after hours hyperbaric

U.S. Naval Torpedo Station, Keyport (360) 396-2111 or (360) 396-8111

Nearest Non-dive Emergency Medical Facilities:

Virginia Mason Hospital, Hyperbaric Medicine Dept., 925 Seneca Street, Seattle
(206) 583-6433 emergency room

DIVE PLAN

Project:	Rockfish Collection and Clam Surveys
Work window:	Start 0900, end 1700
Project Managers:	Eric Parker, RSS; Susan McGroddy, Windward Environmental
Dates of operation:	August 2008, dates to be decided
Location of Dive:	East Waterway, Seattle
Staging Location:	Harbor Island Marina
Primary Divers:	Eric Parker
	Jeff Christiansen
Tender:	Judd Dunlap
Purpose of Work:	Collect fish for tissue sampling, conduct transect surveys for clam presence.

Number of Dives Anticipated:	15
Maximum depth Anticipated:	50 ft.
Depth for Majority of Work:	40 ft. and shallower
Breathing Gas:	Air

Pre-Dive Procedures:

- The U.S. Coast Guard in Seattle will be provided with an emailed copy of this Dive Plan prior to the dive operations (email sectorseattlewwm@.uscg.mil).
- The Coast Guard VTS will be notified on VHF channel 14 or by phone at (206) 217-6152 on the day of work prior to commencing diving operations and again when work is finished for the day.
- A pre-dive briefing will be conducted to familiarize divers and surface personnel of site-specific hazards and to ensure readiness to work.

General Work Plan:

- Operations will be conducted from the *Carolyn Dow*, a 36' aluminum landing craft anchored adjacent to the dive location.
- Divers will be connected to eachother via a safety line.
- Divers and tender will communicate via single side band wireless equipment.

Safety Procedures:

- Diving operations will be conducted in accordance with federal and state health and safety regulations and according to procedures outlined in the RSS Dive Safety Manual. The Windward Site Specific Health and Safety Plan will apply to non-diving components of this operation and will be reviewed by all participants.
- The operation will be checked in with Seattle VTS as a non-participant and will monitor VHF channels 14 and 13. No special vessel consideration (such as a no wake zone) is requested.
- A red-and-white diver flag and blue-and-white alpha flag will be flown conspicuously when divers are in the water.
- Contamination precautions will include a drysuit with attached latex hood and gloves and positive pressure full-face mask.
- Emergency oxygen will be available on site in case of a pressure-related injury. In addition to administration of oxygen to an injured diver, basic first aid and activation of EMS will apply.

Area of operations:

Attachment 2. Field Team Health and Safety Plan Review

I have read a copy of the Health and Safety Plan, which covers field activities that will be conducted to investigate potentially contaminated areas in the EW. I understand the health and safety requirements of the project, which are detailed in this Health and Safety Plan.

Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date

APPENDIX B

Field Collection Forms

Appendix B. Field Collection Forms

This appendix contains the following forms that will be used, as necessary, during this study:

- Protocol Modification Form
- Target Species Tally Form
- Non-Target Species Tally Form
- Mussel and Shrimp Collection Form
- Specimen Label
- Composite Sample Form

PROTOCOL MODIFICATION FORM

Project Name and Number: **EW RIFS – Fish and crab sampling (08-08-09-41)**

Material to be Sampled:

Measurement Parameter:

Standard Procedure for Field Collection & Laboratory Analysis (cite reference):

Reason for Change in Field Procedure or Analysis Variation:

Variation from Field or Analytical Procedure:

Special Equipment, Materials or Personnel Required:

Initiator's Name: Date:

Project Manager: Date:

QA Manager: Date:

WindWard environmental LLC

TARGET SPECIES TALLY FORM

Project Name: EW RI/FS – Fish and crab sampling **Project #: 08-08-09-41**

Species sampled: **Field crew initials:**

Comments:

COLLECTION DATE	COLLECTION TIME	LOCATION ID	COLLECTION METHOD	SPECIMEN ID #	LENGTH (mm)	WEIGHT (g)	GENDER	COMMENTS

NON-TARGET SPECIES TALLY FORM

Project Name: EW RI/FS – Fish and crab sampling **Project #: 08-08-09-41**

Field crew initials:

Comments:

COLLECTION DATE	COLLECTION TIME	LOCATION ID	COLLECTION METHOD	SPECIES	LENGTH RANGE (mm)	TOTAL WEIGHT (g ww)	COUNT	COMMENTS

MUSSEL/SHRIMP COLLECTION FORM

Project Name: EW RI/FS – Fish and crab sampling **Project #: 08-08-09-41**

Field crew initials:

Comments:

COLLECTION DATE	COLLECTION TIME	LOCATION ID	X	Y	SPECIMEN ID #	SPECIES	NO. OF INDIVIDUALS	TOTAL WEIGHT (g ww)	COMMENTS

SPECIMEN LABEL

WINDWARD ENVIRONMENTAL LLC 200 WEST MERCER STREET, SUITE 401, SEATTLE, WA 98119 TEL: (206) 378-1364 FAX: (206) 217-0089	
Project #: **08-08-09-41**	Sampler:
Sampling date:	Retrieval time:
Location:	
Sample ID #:	
Comments:	

COMPOSITE SAMPLE FORM

Project Name: EW RI/FW – Fish and crab sampling **Project #: 08-08-09-41**

Date Composited: **Composited By:**

COMPOSITE SAMPLE ID #	SPECIMEN ID #	COLLECTION DATE	COLLECTION TIME	WEIGHT (g ww)

Comments:

APPENDIX C

Data Management

Appendix C Data Management

AVERAGING LABORATORY REPLICATE SAMPLES

Chemical concentrations obtained from the analysis of laboratory replicate samples (two or more analyses of the same sample) will be averaged for a closer representation of the "true" concentration as compared to the result of a single analysis. Averaging rules are dependent on whether the individual results are detected concentrations or reporting limits (RLs) for undetected chemicals. If all concentrations are detected for a single chemical, the values are simply averaged arithmetically for the sample and its associate laboratory replicate sample(s). If all concentrations are undetected for a given parameter, the minimum RL is selected. If the concentrations are a mixture of detected concentrations and RLs, any two or more detected concentrations are averaged arithmetically and RLs ignored. If there is a single detected concentration and one or more RLs, the detected concentration is reported. The latter two rules are applied regardless of whether the RLs are higher or lower than the detected concentration.

LOCATION AVERAGING

Results of chemical concentrations of discrete samples collected at a single sampling location that are submitted to the laboratory as individual samples and analyzed separately will be averaged for the purposes of mapping a single concentration per location. The averaging rules used for location averaging are the same as for laboratory replicate samples described above. This type of averaging is performed when multiple sediment samples are collected from the same location at the same time. For example: a sample and its field duplicate sample, often referred to as a split sample (PSEP 1997).

SIGNIFICANT FIGURES AND CALCULATIONS

Analytical laboratories report results with various numbers of significant figures depending on the laboratory's standard operating procedures, the instrument, the chemical, and the reported chemical concentration relative to the RL. The reported (or assessed) precision of each result is explicitly stored in the project database by recording the number of significant figures. Tracking of significant figures is used when calculating analyte sums and performing other data summaries. When a calculation involves addition, such as totaling PCBs, the calculation can only be as precise as the least precise number that went into the calculation. For example:

> 210 + 19 = 229 would be reported as 230 because although 19 is reported to 2 significant digits, the trailing zero in the number 210 is not significant.

When a calculation involves multiplication or division, the final result is rounded at the end of the calculation to reflect the value used in the calculation with the fewest significant figures. For example:

59.9 × 1.2 = 71.88 would be reported as 72 because there are two significant figures in the number 1.2.

When rounding, if the number following the last significant figure is less than 5, the digit is left unchanged. If the number following the last significant figure is equal to or greater than 5, the digit is increased by 1.

Many of the Washington State Sediment Management Standards (SMS) chemical criteria are in units normalized to the TOC content in the sediment sample (i.e., milligrams per kilogram organic carbon [mg/kg OC]). Only samples with TOC concentrations greater than or equal to 0.5% or less than or equal to 4.0% are considered appropriate for OC normalization. Samples with TOC concentrations less than 0.5% or greater than 4.0% are compared to dry weight chemical criteria. Chemical concentrations originally in units of micrograms per kilogram (µg/kg) dry weight were converted to mg/kg OC using the following equation:

$$\frac{(C_{\mu g/kg\ dry\ weight}) \times (0.001\ mg/\mu g)}{TOC}$$

Where:

C	=	the chemical concentration
TOC	=	the percent total organic carbon on a dry weight basis, expressed as a decimal (e.g., 1% = 0.01)

BEST RESULT SELECTION FOR MULTIPLE RESULTS

In some instances, the laboratory generates more than one result for a chemical for a given sample. Multiple results can occur for several reasons, including: 1) the original result did not meet the laboratory's internal quality control (QC) guidelines, and a reanalysis was performed; 2) the original result did not meet other project data quality objectives, such as a sufficiently low RL, and a reanalysis was performed; or 3) two different analytical methods were used for that chemical. In each case, a single best result is selected for use. The procedures for selecting the best result differ depending on whether a single or multiple analytical methods are used for that chemical.

For the same analytical method, if the results are:

- Detected and not qualified, then the result from the lowest dilution is selected, unless multiple results from the same dilution are available, in which case, the result with the highest concentration is selected.
- A combination of estimated and unqualified detected results, then the unqualified result is selected. This situation most commonly occurs when the original result is outside of calibration range, thus requiring a dilution.
- All estimated, then the "best result" is selected using best professional judgment in consideration of the rationale for qualification. For example, a result qualified based on laboratory replicate results outside of QC objectives

for precision would be preferred to a qualified result that is outside the calibration range.

- A combination of detected and undetected results, then the detected result is selected. If there is more than one detected result, the applicable rules for multiple results (as discussed above) are followed.
- All undetected results, then the lowest RL is selected.

If the multiple results are from different analytical methods, then the result from the preferred method specified in the quality assurance project plan (QAPP) or based on the consensus of the professional opinions of project chemists was selected.

The following rules are applied to multiple results from different analytical methods:

- For detected concentrations analyzed by the SVOC full-scan and selective ion monitoring (SIM) methods (i.e., PAHs), the highest detected concentration is selected. If the result by one method is detected and the result by the other method is not detected, then the detected result is selected for reporting, regardless of the method. If results are reported as non-detected by both methods, the undetected result with the lowest RL is selected. The SIM method is more analytically sensitive than the full-scan SVOC method, and the undetected results are generally reported at a lower RL by the SIM method than by the full-scan method. Therefore, the SIM method is selected for non-detected results unless an analytical dilution or analytical interferences elevated the SIM RL above the SVOC full-scan RL.
- Hexachlorobenzene and hexachlorocyclopentadiene are analyzed by EPA Methods 8081A, 8270, and/or 8270-SIM. The result from the method with the greatest sensitivity (i.e., lowest RL) is selected if all results are undetected. EPA Method 8081A results are generally selected, when available, because the standard laboratory RLs from this analysis are significantly lower than those from EPA Methods 8270 and 8270-SIM. When chemicals are detected, the detected result with the highest concentration is selected unless the detected concentration is qualified as estimated or tentatively identified, in which case the rule designating treatment of qualified and unqualified data would apply.

CALCULATED TOTALS

Total PCBs, total dichloro-diphenyl-trichloroethane (DDTs), total PAHs, and total chlordane are calculated by summing the detected values for the individual components available for each sample. For individual samples in which none of the individual components is detected, the total value is given a value equal to the highest RL of an individual component, and assigned the same qualifier (U or UJ), indicating an undetected result. Concentrations for the analyte sums are calculated as follows:

- **Total PCBs** are calculated, in accordance with the methods of the SMS, using only detected values for seven Aroclor mixtures.[1] For individual samples in which none of the seven Aroclor mixtures is detected, total PCBs are given a value equal to the highest RL of the seven Aroclors and assigned a U-qualifier indicating the lack of detected concentrations.
- **Total low-molecular-weight PAHs (LPAHs), high-molecular-weight PAHs (HPAHs), PAHs, and benzofluoranthenes** are also calculated in accordance with the methods of the SMS. Total LPAHs are the sum of detected concentrations for naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. Total HPAHs are the sum of detected concentrations for fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene. Total benzofluoranthenes are the sum of the b (i.e., benzo(b)fluoranthene), j, and k isomers. Because the j isomer is rarely quantified, this sum is typically calculated with only the b and k isomers. For samples in which all individual compounds within any of the three groups described above are undetected, the single highest RL for that sample represents the sum.
- **Total DDTs** are calculated using only detected values for the DDT isomers: 2,4'-DDD; 4,4'-DDD; 2,4'-DDE; 4,4'-DDE; 2,4'-DDT; and 4,4'-DDT. For individual samples in which none of the isomers are detected, total DDTs are given a value equal to the highest RL of the six isomers and assigned a U-qualifier, indicating the lack of detected concentrations.
- **Total chlordane** is calculated using only detected values for the following compounds: alpha-chlordane, gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor. For individual samples in which none of these compounds is detected, total chlordane is given a value equal to the highest RL of the five compounds listed above and assigned a U-qualifier, indicating the lack of detected concentrations.

CALCULATION OF PCB CONGENER TEQS

PCB congener toxic equivalents (TEQs) are calculated using the World Health Organization (WHO) consensus toxic equivalency factor (TEF) values for fish, birds (Van den Berg et al. 1998), and mammals (Van den Berg et al. 2006) as presented in Table E-1. The TEQ is calculated as the sum of each congener concentration multiplied by the corresponding TEF value. When the congener concentration is reported as non-detected, then the TEF is multiplied by half the RL.

[1] Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

Table C-1. PCB congener TEF values

PCB Congener Number	TEF Value for Fish (unitless)	TEF Value for Birds (unitless)	TEF Value for Mammals (unitless)
77	0.0001	0.05	0.0001
81	0.0005	0.1	0.0003
105	<0.000005	0.0001	0.00003
114	<0.000005	0.0001	0.00003
118	<0.000005	0.00001	0.00003
123	<0.000005	0.00001	0.00003
126	0.005	0.1	0.1
156	<0.000005	0.0001	0.00003
157	<0.000005	0.0001	0.00003
167	<0.000005	0.00001	0.00003
169	0.00005	0.001	0.03
189	<0.000005	0.00001	0.00003

PCB – polychlorinated biphenyl
TEF – toxic equivalency factor

Calculation of Dioxin/Furan Congener TEQs

Dioxin/furan congener TEQs are calculated using the WHO consensus TEF values (Van den Berg et al. 2006) for mammals as presented in Table E-2. The TEQ is calculated as the sum of each congener concentration multiplied by the corresponding TEF value. When the congener concentration is reported as undetected, then the TEF is multiplied by half the RL.

Table C-2. Dioxin/Furan congener TEF values for mammals

Dioxin/Furan Congener	TEF Value (unitless)
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.01
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.01
1,2,3,4,7,8-Hexachlorodibenzofuran	0.1
1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	0.1
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	0.1
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,7,8-Pentachlorodibenzofuran	0.03
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin	1
2,3,4,6,7,8-Hexachlorodibenzofuran	0.1
2,3,4,7,8-Pentachlorodibenzofuran	0.3
2,3,7,8-Tetrachlorodibenzofuran	0.1

DIOXIN/FURAN CONGENER	TEF VALUE (unitless)
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1
Octachlorodibenzofuran	0.0003
Octachlorodibenzo-p-dioxin	0.0003

TEF – toxic equivalency factor

CALCULATION OF CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS

Carcinogenic polycyclic aromatic hydrocarbons (cPAH) values are calculated using TEF values (California EPA 1994; Ecology 2001) based on the individual PAH component's relative toxicity to benzo(a)pyrene. TEF values are presented in Table E-3. The cPAH is calculated as the sum of each individual PAH concentration multiplied by the corresponding TEF value. When the individual PAH component concentration is reported as non-detected, then the TEF is multiplied by half the RL.

Table C-3. cPAH TEF values

cPAH	TEF VALUE (unitless)
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Bibenz(a,h)anthracene	0.4
Indeno(1,2,3-cd)pyrene	0.1
Chrysene	0.01

cPAH – carcinogenic polycyclic aromatic hydrocarbon
TEF – toxic equivalency factor

REFERENCES

California EPA. 1994. Health effects of benzo(a)pyrene. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Berkeley, CA.

Ecology. 2001. Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC. Publication No. 94-06. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final report. Prepared for the US Environmental Protection Agency, Seattle, WA. Puget Sound Water Quality Action Team, Olympia, WA.

Van den Berg M, Birnbaum L, Bosveld ATC, Brunström B, Cook P, Feeley M, Giesy JP, Hanberg A, Hasegawa R, Kennedy S, Kubiak T, Larsen JC, van Leeuwen FXR, Djien Liem AK, Nolt C, Peterson RE, Poellinger L, Safe S, Schrenk D, Tillitt D, Tysklind M, Younes M, Waern F, Zacharewski T. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Health Perspec 106(12):775-792.

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Tox Sci 93(2):223-241.

APPENDIX D

Risk-based Analytical Concentration Goals

Appendix D. Risk-based Analytical Concentration Goals

D.1 INTRODUCTION

This appendix addresses the following question:

Are standard analytical methods proposed for the chemical analyses of fish, crab, shrimp, and mussel tissue sufficiently sensitive to meet the needs of the East Waterway (EW) ecological and human health risk assessments?

To answer this question, standard reporting limits (RLs) and method detection limits (MDLs) were compared to analytical concentration goals (ACGs). ACGs are defined for ecological receptors as the concentration of a chemical in tissue of a receptor or in its food associated with no effects, and defined for human health as the concentration of a chemical in food that has been identified as having an acceptable risk level (e.g., excess cancer risk no higher than 10^{-6} or hazard quotient less than 1.0 for non-cancer risk). ACGs have not been developed by the US Environmental Protection Agency (EPA) Region 10 for the receptors of interest. Therefore, these concentrations were determined by reviewing the toxicological literature for fish and wildlife, and by reviewing human health guidance documents. Although information from the toxicological literature is used in this document, the objective of this memo is not to establish the toxicity reference values (TRVs) to be used for the EW risk assessments. The TRVs to be used in those assessments will be determined in consultation with EPA.

To determine ACGs for this quality assurance project plan (QAPP), risk-based concentrations (RBCs) were identified or derived for each receptor species that either: 1) consumes fish, crabs, shrimp, or mussels (i.e., piscivorous fish, birds, mammals, and humans), or 2) will be assessed for risk based on chemical concentrations in its own tissue (i.e., fish and crabs) (Table D-1). In this appendix, the RBCs for receptor species that consume fish, crabs, shrimp or mussels are identified as dietary RBCs (expressed as the chemical concentration in prey tissue), and the RBCs for receptor species that are based on chemicals in their own tissue are identified as critical tissue residue RBCs. The ACG for a given tissue is equal to the lowest dietary or critical tissue residue RBC for any receptor ingesting or representing that tissue for each chemical. For example, if both humans and river otters consume crabs, the ACG for cadmium in crabs is set by the RBC of the receptor most sensitive to cadmium (the lower of the two RBCs).

The remainder of this appendix is organized as follows:

- Section D.2.0 – RBC derivation methods for each receptor
- Section D.3.0 – Comparison of ACGs to RLs and MDLs
- Section D.4.0 – Tissue mass required for analysis

- Section D.5.0 – Tables
- Section D.6.0 – References

Tables D-1 through D-12 summarize RBCs for all receptors for each chemical, list studies selected for each receptor for the calculation of RBCs, compare ACGs to RLs and MDLs, and summarize tissue mass requirements to meet target RLs and MDLs. These tables are located in Section D.5.0.

D.2 RISK-BASED CONCENTRATIONS

For this QAPP, RBCs are tissue concentrations associated with an acceptable risk level as derived from the ecological toxicity literature or slope factors and RfDs established by EPA for human health assessment. The RBCs are derived using the same process as was used in QAPP prepared for fish and crab sampling for the LDW RI (Windward 2004). In this appendix, RBCs are derived for receptors and exposure pathways that are associated with either fish, crab, shrimp, or mussel tissue samples, as shown in Table D-1.

The following sections describe how RBCs were derived for each receptor. The RBCs for each of the receptors are summarized in Table D-2; this table includes RBCs for chemicals of interest (COIs) presented in Table D-3. This list presents COIs identified for the LDW ERA and HHRA (Windward 2007a, 2007b), which will provide a basis for the analyte list for the EW because sufficient tissue data do not currently exist to provide a site-specific list. The chemicals of potential concern (COPC) list for the EW will be developed once sufficient data are available to conduct a screening evaluation. Available toxicity data for the chemicals in Table D-3 were used to derive RBCs using methods described in the remainder of this section. For some chemicals in Table D-3, no relevant toxicity data were available for certain receptors and thus RBCs were not derived.

D.2.1 Critical tissue residue RBC derivation for the protection of crabs

RBCs derived for the protection of crabs are expressed as chemical concentrations in crab tissue. Critical tissue residue RBCs derived for the protection of crabs were used to determine ACGs for crab tissue samples.

To derive critical tissue residue RBCs for the protection of crabs for this QAPP, toxicity data were reviewed for effects of chemicals on crabs and other decapod crustaceans. Toxicity data for other decapod crustaceans were included because few toxicity studies were available for crabs. No-observed-effect concentrations (NOAELs) and lowest-observed-effect concentrations (LOAELs) in crab or decapod crustacean tissue were identified based on the effect endpoints of growth, reproduction, and survival.

The NOAELs and LOAELs presented in the literature are expressed as chemical concentrations in test species tissue in units of mg/kg wet weight (ww). Table D-2 summarizes RBCs for crabs, including both NOAELs and LOAELs, if available. The

NOAEL-based RBC is the most relevant concentration; LOAEL-based RBCs are presented in case the NOAEL-based RBC is less than the MDL. Table D-4 presents summary information for the studies selected to derive RBCs in crab tissue, including the endpoint, test species, exposure pathway, and reference for each NOAEL and LOAEL shown. The following sections describe the literature search process and the derivation of RBCs for crabs.

Literature search

Studies relating tissue concentrations in crabs to adverse effects were identified from a search of BIOSIS, EPA's ECOTOX database, aquatic life sciences database, USACE's Environmental Residue Effects Database (ERED), and Jarvinen and Ankley (1999). Original sources of toxicity data were obtained and reviewed to verify effects data summarized in the databases as well as the suitability of the studies. The databases were searched for studies that evaluated effects on survival, growth, and reproduction.

Acceptable toxicological data that met the following criteria were compiled for crabs:

- All selected NOAELs and LOAELs were based on laboratory toxicological studies. Studies using field-collected data (i.e., field-collected crabs) were not considered acceptable. Field studies were not used to derive NOAELs and LOAELs because adverse effects observed in organisms from field studies may be attributed to the presence of multiple chemicals and/or other uncontrolled environmental factors, rather than to a single test chemical.
- Selected NOAELs and LOAELs were based preferentially on dietary, sediment, or water exposure studies.

RBCs were derived from the crab study with the lowest LOAEL, and the crab study with the highest NOAEL that was lower than the LOAEL for the same endpoint. If no NOAEL with the same endpoint as the selected LOAEL was available, the NOAEL was selected as the highest NOAEL below the selected LOAEL based on another endpoint (survival, growth, or reproduction).

For chemicals without NOAELs lower than the selected LOAEL, the NOAEL was determined using the following uncertainty factors following EPA Region 10 guidance (EPA 1997):

- Acute or subchronic LOAEL/10
- Chronic or critical lifestage[1] LOAEL/5

[1] Chronic exposure is defined as >15% of an organism's lifespan (Calabrese and Baldwin 1993). Exposure is assumed to be chronic if the duration is greater than 10 weeks for birds and greater than one year for mammals (Sample et al. 1996). For fish, chronic exposure duration was assumed to be 28 days or greater. A critical lifestage is one that occurs during reproduction, gestation, or development (Sample et al. 1996).

- LC50 (or similar)/50

If no crab studies were available, the RBCs were derived from studies with other decapod crustaceans. For some chemicals, no relevant toxicity data were available and RBCs could not be calculated.

RBC Derivation

RBCs for crabs are equal to the LOAELs and NOAELs from the literature toxicity studies. All RBCs are reported on a wet weight basis in crab tissue. If only dry weight concentrations were reported in individual literature toxicity studies, these concentrations were converted to a wet weight basis using assumptions regarding moisture content of crabs, as noted in Table D-4.

D.2.2 Critical tissue residue RBC derivation for the protection of fish

Critical tissue residue RBCs derived for the protection of fish are expressed as chemical concentrations in the whole-body tissue of the two receptor fish species addressed in this QAPP (i.e., brown rockfish and English sole[2]). Critical tissue residue RBCs were derived in this section for those chemicals that will be evaluated using a critical tissue residue approach in the EW ecological risk assessment (ERA) (i.e., mercury, organochlorine pesticides, tributyltin [TBT], PCBs, certain semivolatile organic compounds [SVOCs], and dioxins and furans. These chemicals will be evaluated using a critical tissue residue approach because they are not metabolized or otherwise regulated by fish, and are thus more likely to bioaccumulate in tissue. A dietary approach will be used in the ERA for chemicals that are metabolized or otherwise regulated by fish (i.e., PAHs and metals other than mercury); dietary RBCs for the protection of piscivorous fish (i.e., brown rockfish) are discussed in Section D.2.3.[3] Critical tissue residue RBCs derived for the protection of fish were considered in determining ACGs for brown rockfish and English sole tissue samples.

To derive critical tissue residue RBCs for the protection of fish, toxicity data were reviewed and NOAELs and LOAELs in fish tissue were identified. Effects endpoints considered were growth, reproduction, and survival.

The NOAELs and LOAELs presented in the literature are expressed as chemical concentrations in whole-body fish tissue in units of mg/kg ww. Table D-2 summarizes RBCs for fish, including both NOAELs and LOAELs, if available. The NOAEL-based RBC is the most relevant concentration; LOAEL-based RBCs are presented in case the NOAEL-based RBC is less than the MDL. Table D-5 presents summary information for the studies selected to represent RBCs in fish tissue, including the endpoint, test

[2] Juvenile Chinook salmon are also an ROC for the EW ERA, but will be collected as part of a separate sampling event with its own QAPP.

[3] Dietary RBCs for juvenile Chinook salmon and other non-piscivorous fish (i.e., benthivorous fish) will be derived in the QAPP for the collection of benthic invertebrates.

species, exposure pathway, and reference for each NOAEL and LOAEL shown. The following sections describe the literature search process and the derivation of RBCs for the protection of fish.

Literature search

Studies relating tissue concentrations in fish to adverse effects were identified from a search of BIOSIS, EPA's ECOTOX database, aquatic life sciences database, USACE's Environmental Residue Effects Database (ERED), and Jarvinen and Ankley (1999). Original sources of toxicity data were obtained and reviewed to verify effects data summarized in the databases as well as the suitability of the studies. The databases were searched for studies that evaluated effects on survival, growth, and reproduction.

Acceptable toxicological data that met the following criteria were compiled for fish.

All selected NOAELs and LOAELs were based on laboratory toxicological studies. Studies using field-collected data (i.e., field-collected fish or fish fed field-collected diets) were not considered acceptable. Field studies were not used to derive NOAELs and LOAELs because adverse effects observed in organisms from field studies may be attributed to the presence of multiple chemicals and/or other uncontrolled environmental factors, rather than to a single test chemical.

Selected NOAELs and LOAELs were based preferentially on dietary, sediment, or water exposure studies. Studies conducted using intraperitoneal (IP) or egg injection or oral gavage as exposure routes were not considered representative of the ROC exposure conditions but were used if no other studies were available.

All selected NOAELs and LOAELs were based on whole-body tissue concentrations or egg concentrations that were converted to adult tissue concentrations using adult-to-egg conversion factors from the literature.

RBCs were derived from the study with the lowest LOAEL, and the study with the highest NOAEL that was lower than the LOAEL for the same endpoint. If no NOAEL with the same endpoint as the selected LOAEL was available, the NOAEL was selected as the highest NOAEL below the selected LOAEL based on another endpoint (survival, growth, or reproduction).

For chemicals without NOAELs lower than the selected LOAEL, the NOAEL was determined using the following uncertainty factors following EPA Region 10 guidance (EPA 1997):

- Acute or subchronic LOAEL/10
- Chronic or critical lifestage LOAEL/5
- LC50 (or similar)/50

For some chemicals, no relevant toxicity data were available and RBCs could not be calculated.

RBC Derivation

RBCs for the protection of fish are equal to the LOAELs and NOAELs from the toxicological literature (Table D-5). All RBCs are reported on a wet weight basis in fish.

D.2.3 Dietary RBC derivation for the protection of piscivorous fish

Dietary RBCs derived for the protection of piscivorous fish are expressed as chemical concentrations in their prey for chemicals that will be evaluated using a dietary approach in the ERA (i.e., PAHs and metals, except mercury). RBCs for other chemicals to be evaluated for fish in the ERA, such as PCBs, mercury, DDT, and TBT, are determined using a critical tissue residue approach (Section D.2.2). Dietary RBCs are expressed as concentrations in fish prey for these chemicals because they are metabolized or otherwise regulated by fish. RBCs derived for prey fish tissue for the protection of piscivorous fish will be considered in the determination of ACGs for English sole, perch, crab, shrimp, and mussel tissue samples described in this QAPP.

RBCs for piscivorous fish represent chemical concentrations in fish prey independent of prey type. For example, brown rockfish consume both English sole and shiner surfperch. Because it is not known what percentage of the rockfish's diet is represented by these two fish species, or what the chemical concentrations would be in tissues of those fish, the dietary RBC for the protection of piscivorous fish is assumed to be the same whether it is applied to English sole or shiner surfperch tissue. Thus, a single dietary RBC will be applicable for any type of prey tissue in the diet and is relevant in setting the ACG for all tissue types consumed by fish.

To derive RBCs for the protection of fish for this QAPP, toxicity data were reviewed for effects of PAHs and metals (other than mercury) on fish species, and NOAELs and LOAELs in fish food were identified. Effects endpoints considered were growth, reproduction, and survival.[4]

The NOAELs and LOAELs derived from the literature are expressed as chemical concentrations in fish prey items in units of mg/kg ww. Table D-2 summarizes RBCs for fish, based on both NOAELs and LOAELs, if available. The NOAEL-based RBC is the most relevant concentration; LOAEL-based RBCs are presented in case the NOAEL-based RBC is less than the MDL. Table D-6 presents summary information for the studies selected to derive RBCs in fish prey items. The summary information in Table D-6 includes the endpoint, test species, exposure pathway, and reference for each NOAEL and LOAEL shown.

Literature Search

The literature search was the same as for the critical tissue residue RBCs, as described in Section D.2.2.

[4] These assessment endpoints will be used in the Phase 2 risk assessments for fish, as discussed in the Phase 2 work plan (Windward 2004b).

RBC Derivation

RBCs for the protection of piscivorous fish are equal to LOAELs and NOAELs derived from the toxicological literature (Table D-6). All RBCs are reported on a wet weight basis in fish food. If only dry weight concentrations were reported in individual literature toxicity studies, these concentrations were converted to a wet weight basis using assumptions regarding moisture content of specific prey for each study, as noted in Table D-6.

D.2.4 Dietary RBC derivation for the protection of birds and mammals

RBCs for the protection of piscivorous birds and mammals are expressed as chemical concentrations in the tissues of their prey. ACGs for specific tissue types will be determined based on the RBCs of the particular bird or mammal receptors consuming those tissues, as listed in Table D-1.

RBCs for wildlife represent chemical concentrations in their prey independent of prey type. For example, river otters may consume fish, crabs, and clams. Because it is not known what percentage of the river otter diet is represented by different types of prey, or what the chemical concentrations would be in the different prey items, the RBC for river otter is assumed to be the same whether it is applied to fish tissue or other prey tissue types.

Toxicity data identified for bird and mammal species were no-observed-adverse-effect levels (NOAELs), which are the highest dietary doses at which no adverse effects were observed, and lowest-observed-adverse-effect levels (LOAELs), which are the lowest dietary doses at which adverse effects were observed. Effects endpoints included growth, reproduction, and survival.[5]

The NOAELs and LOAELs derived from the literature are expressed as dietary doses in mg/kg body weight (bw)/day. These dietary doses were converted to RBCs in prey tissue in mg/kg ww using the receptor's food ingestion rate and body weight (as described in Section D.2.4.2). Table D-2 summarizes wildlife RBCs, including both NOAELs and LOAELs, if available. The NOAEL-based RBC is the most relevant concentration; LOAEL-based RBCs are presented in case the NOAEL-based RBC is less than the MDL. Tables D-7 and D-8 present summary information for the studies selected to derive RBCs in bird and mammal prey items, respectively, including the endpoint, test species, exposure pathway, and reference for each NOAEL and LOAEL shown. The following sections describe the literature search process and the conversion of dietary doses to dietary RBCs.

[5] These assessment endpoints will be used in the Phase 2 risk assessments for wildlife, as discussed in the Phase 2 work plan (Windward 2004b).

Literature Search

Toxicity studies were identified from a search of BIOSIS, EPA's ECOTOX database, the National Library of Medicine's TOXNET database, the US Fish and Wildlife Service's Contaminant Review series, the Oak Ridge National Laboratory's database, and EPA's IRIS database. Original sources of toxicity data were obtained and reviewed to verify effects data summarized in the databases as well as the suitability of the studies. The databases were searched for studies that evaluated effects on survival, growth, and reproduction. The following guidelines were considered in the selection of TRVs for wildlife.

Studies using field-collected data were not used to obtain NOAELs and LOAELs, but were considered if no other toxicity data were available for a COI. Studies conducted using IP injection, intramuscular injection, forced ingestion, or oral gavage as exposure routes were not considered for selecting NOAELs and LOAELs unless no other toxicity data are available for a COI.

Studies using drinking water as the exposure medium were not used to select NOAELs and LOAELs because bioavailability from water may be different from that of food. If no other toxicity data were available, then drinking water studies were considered.

Studies with egg production endpoints for chicken or quail, such as Edens and Garlich (1983) and Edens et al. (1976) are considered highly uncertain and were only considered if data from other more appropriate studies were not available. These data are considered uncertain because chickens and quail have been bred to have high egg-laying rates. Even with a significant reduction in their baseline egg production, these egg production rates may be much higher than those of any wild avian species. These differences in reproductive physiology result in high uncertainty in extrapolating a reproductive effect threshold from egg production rates for chickens or quails.

Toxicity studies conducted with chemical forms not likely found in the EW, such as the fungicide methylmercury dicyandiamide, were not used to select NOAELs and LOAELs. Toxicity of these chemical forms is not comparable to the toxicity of forms of chemicals present in the EW.

RBCs were derived from the study with the lowest LOAEL, and the study with the highest NOAEL that was lower than the LOAEL for the same endpoint. If no NOAEL with the same endpoint as the selected LOAEL was available, the NOAEL was selected as the highest NOAEL below the selected LOAEL based on another endpoint (survival, growth, or reproduction).

For chemicals without NOAELs lower than the selected LOAEL, the NOAEL was determined using the following uncertainty factors following EPA Region 10 guidance (EPA 1997):

- Acute or subchronic LOAEL/10
- Chronic or critical lifestage LOAEL/5
- LC50 (or similar)/50

For some chemicals, no relevant toxicity data were available and RBCs could not be calculated.

RBC Derivation

The NOAELs and LOAELs derived from toxicity studies were expressed as daily dietary doses normalized for body weight. To convert these doses to a tissue concentration in ingested food, the following equation was used:

$$C_F = (\text{Dose} \times \text{BW})/\text{DFC}$$

where:

C_F = concentration in food (mg/kg ww)
Dose = NOAEL or LOAEL (mg/kg bw/day)
BW = body weight (kg)
DFC = daily food consumption rate (kg ww/day)

If the NOAEL or LOAEL was based on a reproductive endpoint, the C_F was calculated using the female BW and DFC. If the NOAEL or LOAEL was based on growth or survival, C_F was calculated using the male and female average for BW and DFC. The BW and DFC values used in deriving RBCs are presented in Table D-9. The lowest calculated C_F for each receptor was chosen as the RBC, as summarized in Table D-2. RBCs are presented for both NOAELs and LOAELs, where available.

D.2.5 Dietary RBC derivation for the protection of humans

RBCs for the protection of humans that might ingest fish, crabs, shrimp, and mussels are expressed as chemical concentrations in those tissue types. Human health guidance documents were reviewed for RBCs for human health. EPA Region 10 has not developed RBCs in food organisms for the protection of human health. EPA Region 9 has developed RBCs for the protection of human health for exposures to soil and water (EPA 1996), but not for consumption of fish tissue. The Model Toxics Control Act (MTCA, a Washington State statute), which contains human health risk-based cleanup levels for several media, considers uptake into tissue (i.e., fish) from surface water but does not directly provide a human health RBC for tissue. EPA Region 3 (EPA 2001) provides an approach for the development of RBCs for fish tissue, which, after modification for site-specific exposure factors, was used to derive RBCs for fish and crab tissue in this appendix.

RBCs can be calculated for chemicals with either carcinogenic or non-carcinogenic endpoints; some chemicals have both types of endpoints. The RBC equations are shown below:

$$RBC(carcinogenic) = \frac{TR \times BW \times AT_c}{EF \times ED \times IR \times CF \times CSF}$$

$$RBC(noncarcinogenic) = \frac{THQ \times RfD \times BW \times AT_n}{EF \times ED \times IR \times CF}$$

where:

TR = target risk (1×10^{-6})
BW = body weight (79 kg)
AT_c = averaging time, carcinogenic (25,550 days)
EF = exposure frequency (365 days/yr)
ED = exposure duration (70 years)
IR = ingestion rate (98 g/day)
CF = conversion factor (0.001 kg/g)
CSF = cancer slope factor (kg-day/mg, chemical-specific)
THQ = target hazard quotient (0.1, EPA 1996)
RfD = reference dose (mg/kg-day, chemical-specific)
AT_n = averaging time, non-carcinogenic (25,550 days)

For calculation of RBCs(cargenogenic) for certain PCBs and dioxins, the CSF of the index comound ($CSF_{i.c.}$) is multiplied by the TEF (Van den Berg et al. 2006) as follows to calculate the RBC:

$$RBC(carcinogenic) = \frac{TR \times BW \times AT_c}{EF \times ED \times IR \times CF \times CSF_{i.c.} \times TEF}$$

The seafood ingestion rate is the 95th percentile rate for the combined consumption of pelagic fish, benthic fish, and shellfish as estimated in the Tulalip Tribes fish consumption survey (Toy et al. 1996). For calculation of RBCs for tissue presented in this document, the Region 3 RBC values were adjusted using the parameters provided in the equations above.

D.3 COMPARISON OF ACGS TO MDLS

ACGs were determined for each tissue type that will be analyzed (i.e., brown rockfish, English sole, perch, crab, shrimp, and mussel). The ACG for each tissue type was determined by selecting the lowest RBC for each chemical for each receptor associated with that tissue type, as presented in Table D-2. Table D-10 summarizes the RBCs used in deriving the ACG for each tissue type. These ACGs for brown rockfish, English sole, perch, crab, shrimp, and mussel tissue samples are compared with target RLs and MDLs in Table D-11.

As shown in Table D-11, the RLs for 54 of the 106 chemicals or chemical groups with ACGs were less than the ACGs, and thus the specified methods are sufficiently sensitive to provide definitive data for the risk assessments for those chemicals. However, the RLs for 52 other chemicals or chemical groups were higher than the ACGs derived for human health or ecological RBCs, and MDLs for 37 chemicals were higher than ACGs. The target RLs and MDLs in Table D-11 are the lowest that can be reasonably obtained using standard EPA-approved analytical methods. The chemicals with RLs higher than ACGs are 22 SVOCs, 7 individual PCB Aroclors, total PCBs, dioxin and furan congeners, 16 organochlorine pesticides, total and inorganic arsenic, antimony, thallium, and mercury. The chemicals with MDLs higher than ACGs are 11 SVOCs, 6 individual PCB Aroclor, total PCBs, dioxin and furan congeners, 15 organochlorine pesticides, total and inorganic arsenic, and mercury.

Total PCBs, PAHs, total arsenic, and mercury were frequently detected at concentrations above the RLs presented in Table D-10 in tissue collected during the LDW RI. In addition, dioxins and furans were frequently detected in fish tissue collected in 2007 near Kellogg Island and along the Elliott Bay waterfront (Gries 2008). Therefore, it is expected that EW data for these chemicals should be sufficient for use in the risk assessments, because elevated RLs relative to ACGs are only problematic when chemicals are not detected.

For SVOCs, PCB Aroclors, pesticides, and inorganic arsenic, the RLs were higher than ACGs for human receptors only, with the exception of three pesticides. The RLs for these three pesticides (aldrin, endosulfan, and endrin) were higher than ACGs for pigeon guillemot, rockfish, or English sole. Therefore, application of the cited analytical methods could result in some uncertainty regarding whether these chemicals represent a significant risk if they were undetected using these standard methods, primarily in the human health assessment for SVOCs, PCB Aroclors, and pesticides. For the undetected chemicals with RLs above the ACGs, the ramifications for the HHRA and ERA will be discussed in the uncertainty assessments.

The laboratories will make all reasonable efforts to achieve the target MDLs and RLs for all chemicals. Additional efforts may include modified extraction techniques (e.g., extracting a higher sample volume or adjusting the final extract volume), sample cleanup procedures (e.g., gel-permeation column chromatography), using a lower concentration for the lowest standard in the initial calibration, or adjusting the amount of extract injected into the instrument. Some samples may also be re-analyzed on instruments that yield lower RLs and MDLs (e.g., by graphite furnace atomic absorption). If no PCB Aroclors are detected in a sample, a low-level extraction technique may also be performed. Lower target MDLs and RLs may be available for pesticides using a GC/MS/MS technique developed by Columbia Analytical Services, Inc., although the target MDLs and RLs are not yet known.

D.4 TISSUE MASS REQUIRED FOR ANALYSIS

The amount of tissue mass required to meet the target RLs and MDLs presented in Table D-12. This information is presented in the QAPP to set the minimum amount of tissue mass to be targeted for collection.

For English sole, perch, brown rockfish, and crab, the standard tissue mass required to meet the target RLs and MDLs for all analytes in Table D-11 is 200 g per composite tissue sample (Table D-12). It should not be difficult to collect this amount of tissue mass for fish tissue samples. However, it may be difficult to collect enough tissue mass for crab edible meat and hepatopancreas samples, shrimp, and mussels. The RLs and MDLs will increase proportionally as the tissue mass decreases.[6] Specifically, if the required tissue mass is decreased by an order of magnitude, the detection limit will increase by an order of magnitude. Therefore, the relationship between target RLs/MDLs and tissue mass will be further evaluated once actual composite tissue sample masses are known.

D.5 TABLES

Table D-1. Receptors, exposure pathways, and tissue types for RBCs

RECEPTOR[A]	RISK ASSESSMENT APPROACH	TISSUE TYPE ASSOCIATED WITH RBC
Crab	Critical tissue residue	Crab tissue
Brown rockfish	Critical tissue residue	whole-body brown rockfish tissue
	Dietary	prey tissue (whole-body English sole, whole-body perch, crab, mussels, and shrimp)
English sole	Critical tissue residue	whole-body English sole tissue
Pigeon Guillemot	Dietary	prey tissue (whole-body English sole, whole-body brown rockfish, whole-body perch, crab, and shrimp)
Osprey	Dietary	prey tissue (whole-body rockfish, whole-body English sole, and whole-body perch)
River otter	Dietary	prey tissue (whole-body rockfish, whole-body English sole, whole-body perch, crab, shrimp, and mussels)
Harbor seal	Dietary	prey tissue (whole-body rockfish, whole-body English sole, and whole-body perch)

[6] Conversely, it may be possible to decrease MDLs and RLs by increasing tissue mass, although the laboratory may need to use cleanup methods to remove matrix interferences. The MDLs and RLs presented in Table D-11 are based on optimal tissue amounts using the laboratory's established standard operating procedures and cleanup methods, without analytical dilutions.

RECEPTOR[A]	RISK ASSESSMENT APPROACH	TISSUE TYPE ASSOCIATED WITH RBC
Humans	Dietary	prey tissue (whole-body rockfish, whole-body English sole; English sole fillet, whole-body perch; crab, shrimp, and mussels)

[a] Juvenile Chinook salmon will be receptors of concern for the ERA but are not addressed in this QAPP because they will be collected as part of a separate sampling event. Prey of juvenile Chinook salmon (i.e., benthic invertebrates) will also be collected as part of a separate sampling event.

Table D-2. Receptor-specific dietary and critical tissue residue RBCs for fish, crabs, shrimp, and mussels

Analyte	Dietary RBC (mg/kg ww)											Critical Tissue Residue RBC (mg/kg ww)			
		Osprey		Pigeon Guillemot		River Otter		Harbor Seal		Piscivorous Fish		Fish		Crab	
	Human Health	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
PAHs															
Acenaphthene	5.0	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Acenaphthylene	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Anthracene	25	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Benzo(a)anthracene	0.0011	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Benzo(a)pyrene	0.00011	1.4	7.1	1.4	7.0	12	60	64	320	100	116	na	na	na	na
Benzo(b)fluoranthene	0.0011	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Benzo(k)fluoranthene	0.011	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Benzo(g,h,i)perylene	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Chrysene	0.11	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Dibenzo(a,h)anthracene	0.00011	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Dibenzofuran	0.084	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Fluoranthene	3.4	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Fluorene	3.4	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Indeno(1,2,3-cd)pyrene	0.0011	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1-Methylnaphthalene	na	na	na	na	na	910	na	4,800	na	na	na	na	na	na	na
2-Methylnaphthalene	0.34	na	na	na	na	330	690	1,700	3,700	na	na	na	na	na	na
Naphthalene	1.7	na	na	na	na	810	na	4,300	na	na	na	na	na	0.005	0.05
Phenanthrene	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Pyrene	2.5	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Total PAHs	na	40	200	40	200	na	na	na	na	324	951	na	na	na	na
Other SVOCs															
1,2,4-Trichlorobenzene	0.84	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1,2-Dichlorobenzene	7.6	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1,3-Dichlorobenzene	0.25	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1,4-Dichlorobenzene	0.034	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Analyte	Dietary RBC (mg/kg ww)												Critical Tissue Residue RBC (mg/kg ww)			
	Human Health	Osprey		Pigeon Guillemot		River Otter		Harbor Seal		Piscivorous Fish			Fish		Crab	
		NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based		NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
2,4,5-Trichlorophenol	8.4	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,4,6-Trichlorophenol	0.073	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,4-Dichlorophenol	0.25	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,4-Dimethylphenol	1.7	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,4-Dinitrophenol	0.17	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,4-Dinitrotoluene	0.17	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,6-Dinitrotoluene	0.084	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2-Chloronaphthalene	6.7	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2-Chlorophenol	0.42	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2-Methylphenol	4.2	na	na	na	na	na	na	na	na	na	na		na	na	na	na
3,3'-Dichlorobenzidine	0.0018	na	na	na	na	na	na	na	na	na	na		na	na	na	na
4-Chloroaniline	0.34	na	na	na	na	na	na	na	na	na	na		na	na	na	na
4-Methylphenol	0.42	na	na	na	na	na	na	na	na	na	na		1.53	76.5	na	na
4-Nitrophenol	na	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Aniline	0.14	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Benzidine	0.0000035	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Benzoic acid	340	na	na	na	na	490	4,500	2,600	24,000	na	na		3.38	na	na	na
Benzyl alcohol	42	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Bis(2-chloroethyl)ether	0.00073	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Bis(2-ethylhexyl)phthalate	0.058	330	1,700	330	1,600	260	540	1,400	2,900	na	na		0.39	1.6	na	na
Bis-chloroisopropyl ether	0.00073	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Butyl benzyl phthalate	17	na	na	na	na	1,500	4,500	8,000	24,000	na	na		6.45	na	na	na
Carbazole	0.040	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Di-ethyl phthalate	67	na	na	na	na	11,000	22,000	59,000	120,000	na	na		1.10	na	na	na
Dimethyl phthalate	na	na	na	na	na	na	na	na	na	na	na		0.498	na	na	na
Di-n-butyl phthalate	8.4	na	na	na	na	96	480	510	2,600	na	na		1.17	na	na	na
Hexachlorobutadiene	0.010	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Hexachloroethane	0.058	na	na	na	na	na	na	na	na	na	na		na	na	na	na

Analyte	Dietary RBC (mg/kg ww)											Critical Tissue Residue RBC (mg/kg ww)			
	Human Health	Osprey		Pigeon Guillemot		River Otter		Harbor Seal		Piscivorous Fish		Fish		Crab	
		NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
Isophorone	0.85	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Nitrobenzene	0.042	na	na	na	na	na	na	na	na	na	na	na	na	na	na
N-Nitrosodimethylamine	0.000016	na	na	na	na	na	na	na	na	na	na	na	na	na	na
N-Nitrosodi-n-propylamine	0.00012	na	na	na	na	na	na	na	na	na	na	na	na	na	na
N-Nitrosodiphenylamine	0.16	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Pentachlorophenol	0.0067	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Phenol	25	na	na	na	na	360	720	1,900	3,800	na	na	1.47	73.4	na	na
PCBs															
Aroclor 1016	0.012	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Aroclor 1221	0.00040	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Aroclor 1232	0.00040	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Aroclor 1242	0.00040	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Aroclor 1248	0.00040	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Aroclor 1254	0.00040	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Aroclor 1260	0.00040	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Total PCBs	0.00040	2.3	6.7	2.4	7.0	0.27	0.53	1.4	2.8	na	na	0.104	0.520	0.110	1.10
PCB congeners (based on 2,3,7,8-TCDD)[a]	na	7.1×10^{-6}	7.1×10^{-5}	7.0×10^{-5}	7.0×10^{-4}	4.2×10^{-6}	3.2×10^{-5}	2.2×10^{-5}	1.7×10^{-4}	na	na	2.4×10^{-6}	1.2×10^{-5}	na	na
PCB-77[a]	0.000054	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-81[a]	0.000018	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-105[a]	0.00018	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-114[a]	0.00018	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-118[a]	0.00018	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-123[a]	0.00018	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-126[a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-156[a]	0.00018	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-157[a]	0.00018	na	na	na	na	na	na	na	na	na	na	na	na	na	na
PCB-167[a]	0.00018	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Analyte	Dietary RBC (mg/kg ww)												Critical Tissue Residue RBC (mg/kg ww)			
		Osprey		Pigeon Guillemot		River Otter		Harbor Seal		Piscivorous Fish			Fish		Crab	
	Human Health	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based		NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
PCB-169 [a]	1.8×10^{-7}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
PCB-189 [a]	0.00018	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Dioxins/furans																
2,3,7,8-tetrachlorodibenzo-*p*-dioxin [a]	5.4×10^{-9}	7.1×10^{-6}	7.1×10^{-5}	7.0×10^{-5}	7.0×10^{-4}	4.2×10^{-6}	3.2×10^{-5}	221×10^{-5}	1.7×10^{-4}	na	na		2.4×10^{-6}	1.2×10^{-5}	na	na
1,2,3,7,8-pentachlorodibenzo-*p*-dioxin [a]	5.4×10^{-9}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin [a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,4,7,8-hexachlorodibenzo-*p*-dioxin [a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin [a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin [a]	5.4×10^{-7}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Octachlorodibenzo-*p*-dioxin [a]	1.8×10^{-5}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,3,7,8-tetrachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,7,8-pentachlorodibenzofuran [a]	1.8×10^{-7}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,3,4,7,8-pentachlorodibenzofuran [a]	1.8×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,6,7,8-hexachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,7,8,9-hexachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,4,7,8-hexachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
2,3,4,6,7,8-hexachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na	na	na	na	na	na	na		na	na	na	na
1,2,3,4,6,7,8-heptachlorodibenzofuran [a]	5.4×10^{-7}	na	na	na	na	na	na	na	na	na	na		na	na	na	na

Analyte	Dietary RBC (mg/kg ww)											Critical Tissue Residue RBC (mg/kg ww)			
		Osprey		Pigeon Guillemot		River Otter		Harbor Seal		Piscivorous Fish		Fish		Crab	
	Human Health	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
1,2,3,4,7,8,9-heptachlorodibenzofuran [a]	5.4×10^{-7}	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Octachlorodibenzofuran [a]	1.8×10^{-5}	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Metals															
Antimony	0.034	na	na	na	na	9,000	na	48,000	na	na	na	na	na	na	na
Arsenic	0.00054	51	200	50	200	16	33	84	170	20	30	na	na	1.28	na
Cadmium	0.084	7.5	20	7.5	20	21	79	110	420	0.1	0.5	na	na	0.6	2.6
Chromium	0.25	5.1	25	5.0	25	8,900	na	47,000	na	9.42	na	na	na	1	3.2
Cobalt	na	12	120	12	120	0.61	6.1	3.2	32	na	na	na	na	na	na
Copper	3.4	100	14	100	140	110	160	570	830	50	100	na	na	50	na
Lead	na	30	100	29	100	66	540	350	2,900	7,040	na	na	na	na	na
Mercury	0.0084	0.090	0.45	0.09	0.45	0.010	0.051	0.055	0.27	na	na	0.23	0.47	0.99	1
Molybdenum	0.42	30	150	30	150	1.5	15	8.2	82	na	na	na	na	na	na
Nickel	1.7	380	530	380	530	50	120	270	640	na	na	na	na	na	na
Selenium	0.42	2.5	4.2	2.5	4.1	0.33	0.49	1.8	2.6	3.5	6.6	1.2	1.6	na	na
Silver	0.42	na	na	na	na	na	na	na	na	3,000	na	na	na	na	na
Thallium	0.0059	12	120	12	120	4.5	na	24	na	na	na	na	na	na	na
Vanadium	0.084	6.0	11	6.0	12	6.4	16	34	87	2.04	10.2	na	na	0.6	na
Zinc	25	410	620	410	620	960	1,900	5,100	10,000	1,900	2,000	na	na	12.7	35.2
Di-n-butyltin	na	na	na	na	na	23	45	120	240	na	na	na	na	na	na
Tri-n-butyltin	0.025	7.1	18	7.0	18	2.4	12	13	64	na	na	0.018	0.159	0.12	na
Organochlorine Pesticides															
4,4'-DDD	0.0034	na	na	na	na	na	na	na	na	na	na	na	na	na	na
4,4'-DDE	0.0024	na	na	na	na	na	na	na	na	na	na	na	na	na	na
4,4'-DDT	0.0024	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Total DDT	na	0.32	1.6	0.32	1.6	7.2	7.8	38	41	na	na	1.8	1.8	0.046	0.060
Aldrin	0.000048	0.040	0.20	0.040	0.20	5.0	25	27	130	na	na	na	na	na	na
alpha-BHC	0.00013	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Analyte	Dietary RBC (mg/kg ww)												Critical Tissue Residue RBC (mg/kg ww)			
	Human Health	Osprey		Pigeon Guillemot		River Otter		Harbor Seal		Piscivorous Fish			Fish		Crab	
		NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based		NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
beta-BHC	0.00045	na	na	na	na	35	190	180	1,000	na	na		na	na	na	na
Chlordane	0.0023	3.0	10	3.0	10	1.1	5.6	5.8	30	na	na		0.71	1.36	0.71	1.70
Dieldrin	0.000050	0.40	0.60	0.40	0.60	0.23	1.1	1.2	6.1	na	na		0.12	0.2	na	na
Endosulfan	0.50	51	na	50	na	5.1	15	27	81	na	na		0.00062	0.031	na	na
Endosulfan sulfate	na	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Endrin	0.025	0.35	1.0	0.35	1.0	2.4	5.5	13	29	na	na		0.0012	0.012	na	na
gamma-BHC (Lindane)	0.00062	8.1	18	8.0	18	390	na	2,100	na	na	na		9.5	6.1	na	na
Heptachlor	0.00018	2.5	25	2.5	25	6.0	11	32	57	na	na		0.03	1.5	na	na
Heptachlor epoxide	0.000089	na	na	na	na	na	na	na	na	na	na		0.08	0.8	0.054	0.18
Hexachlorobenzene	0.00050	5.6	6.1	5.5	6.0	0.16	0.78	0.83	4.1	na	na		468	na	na	na
Methoxychlor	0.42	180	1,800	170	1,700	100	340	540	1,800	na	na		0.05	0.300	0.015	0.15
Mirex	0.017	na	na	na	na	na	na	na	na	na	na		na	na	na	na
Toxaphene	0.00073	na	na	na	na	na	na	na	na	na	na		na	na	na	na

na – toxicity data not available or not applicable based on the selection criteria discussed in Sections D.2.1.1, D.2.2.1, D.2.3.1, and D.2.4.1. For PCB Aroclors and ecological receptors, RBCs for total PCBs will be used, although the studies used to derive the total PCB RBCs may have been based on individual Aroclors.

[a] Dioxin-like PCB and dioxin/furan congeners will be evaluated as toxic equivalents (TEQs) in the risk assessments, rather than as individual congeners. However, because TEQs are calculated, rather than measured by the laboratory, RBCs for individual congeners are presented to facilitate comparison with RLs for those congeners. In reality, risks will be assessed based on sums of these congeners (normalized per their relative toxicity to TCDD), and thus comparison to RLs on a congener-specific basis is somewhat uncertain.

Table D-3. COIs from LDW RI

METALS	PAHS
Antimony	Acenaphthene
Arsenic (inorganic As and total As)	Acenaphthylene
Cadmium	Anthracene
Chromium	Benzo(a)anthracene
Cobalt	Benzo(a)pyrene
Copper	Benzo(b)fluoranthene
Lead	Benzo(g,h,i)perylene
Mercury	Benzo(k)fluoranthene
Molybdenum	Chrysene
Nickel	Dibenzofuran
Selenium	Dibenzo(a,h)anthracene
Silver	Fluoranthene
Thallium	Fluorene
Vanadium	Indeno(1,2,3-cd)pyrene
Zinc	Naphthalene
BUTYLTINS	Phenanthrene
Dibutyltin as ion	Pyrene
Tributyltin as ion	**PCBS**
Organochlorine Pesticides	Total PCBs (Aroclors and congeners)
4,4'-DDD	**DIOXINS AND FURANS**
4,4'-DDE	2,3,7,8 -TCDD
4,4'-DDT	1,2,3,7,8-PeCDD
Aldrin	1,2,3,4,7,8-HxCDD
alpha-BHC	1,2,3,6,7,8–HxCDD
gamma-BHC	1,2,3,7,8,9-HxCDD
Chlordane (alpha and gamma)	1,2,3,4,6,7,8-HpCDD
Dieldrin	OCDD
Endrin	2,3,7,8 -TCDF
Heptachlor	1,2,3,7,8-PeCDF
Methoxychlor	2,3,4,7,8-PeCDF
SVOCs	1,2,3,4,7,8-HxCDF
1,2-Dichlorobenzene	1,2,3,6,7,8–HxCDF
1,4-Dichlorobenzene	1,2,3,7,8,9-HxCDF
2-methylnaphthalene	2,3,4,6,7,8-HpCDF
2-Methylphenol	1,2,3,4,6,7,8-HpCDF
Benzoic acid	1,2,3,6,7,8,9-HpCDF
Benzyl alcohol	OCDF
Bis(2-ethylhexyl)phthalate	
Di-n-butyl phthalate	
Hexachlorobenzene	
Pentachlorophenol	
Phenol	

Table D-4. Studies selected to derive critical tissue residue RBCs for crabs

Analyte	NOAEL (mg/kg ww)	LOAEL (mg/kg ww)	Endpoint	Test Species	Reference
PAHs					
Naphthalene	0.005[a]	0.05	survival	spot shrimp	Sanborn and Malins (1977)
PCBs					
Total PCBs	0.110[a]	1.10[b]	survival	grass shrimp	Hansen et al.(1974)
Metals and Butyltins					
Arsenic	1.28[c]	na	growth	grass shrimp (juvenile)	Lindsay and Sanders (1990)
Cadmium	0.6 [c]	na	survival	grass shrimp	Rule and Alden (1996)
	na	2.6[c]	survival	grass shrimp	Vernberg et al.(1977)
Chromium	1	3.2	growth	sand crab (juvenile)	Mortimer and Miller (1994)
Copper	50[c]	na	survival	crayfish	Evans (1980)
Mercury	0.99[c]	na	survival	Norway lobster (adult)	Canli and Furness (1995)
	na	1[d,e]	survival	shore crab (adult)	Bianchini and Gilles (1996)
Vanadium	0.6	na	survival	shrimp	Miramand et al.(1981)
Zinc	12.7[c]	35.2[c]	survival	crayfish	Mirenda (1986)
TBT	0.12	na	growth	juvenile blue crab	Rice et al.(1989)
Organochorine pesticides					
Chlordane	0.71	1.70	survival	pink shrimp	Parrish et al.(1976)
Total DDT	na	0.060	survival	pink shrimp	Nimmo et al.(1970)
	0.046	na	survival	crayfish	Johnson et al.(1971)
Heptachlor epoxide	0.054	0.18	survival	pink shrimp	Schimmel et al.(1976)
Methoxychlor	0.015[a]	0.150	survival	Dungeness crab (juvenile)	Armstrong et al.(1976)

Note: Tissue types analyzed include whole body or hepatopancreas.

na – NOAEL or LOAEL not available or not applicable based on the selection criteria discussed in Section D.2.1

[a] Calculated from LOAEL by dividing by 10.

[b] Survival was reduced by 33%.

[c] Converted from dry weight to wet weight using a moisture content of 80%(Jarvinen and Ankley 1999).

[d] Full equilibrium between water and tissue may not have been reached because of a short exposure time (≤ 48 hrs).

[e] Concentration is lowest of three crab species tested (*Carcinus maenas*, *Eriocheir sinensis*, and *Cancer pagurus*).

Table D-5. Studies selected to derive critical tissue residue RBCs for fish

Analyte	NOAEL (mg/kg ww)	LOAEL (mg/kg ww)	Endpoint[A]	Test Species	Reference
SVOCs					
Bis(2-ethylhexyl)phthalate	0.39[b]	1.6[b]	survival	rainbow trout	Mehrle and Mayer (1976)
Butyl benzyl phthalate	6.45	na	survival	bluegill	Barrows et al. (1980)
Di(n)butyl phthalate	1.17	na	survival	sheepshead minnow	Wofford et al. (1981)
Dimethyl phthalate	0.498	na	survival	bluegill	Barrows et al. (1980)
Diethyl phthalate	1.102	na	survival	bluegill	Barrows et al. (1980)
4-methylphenol	1.53[c]	76.5	survival	rainbow trout	Kaiser et al. (1984)
Benzoic acid	3.38	na	survival	mosquito fish	Lu and Metcalf (1975)
Phenol	1.47[c]	73.4	survival	rainbow trout	McKim and Schmeider (1990)
PCBs and Dioxins					
PCBs	0.104 – 0.528[d]	0.520 – 2.64[d]	reproduction	common barbel	Hugla and Thome (1999)
2,3,7,8-TCDD	2.4×10^{-6}	1.2×10^{-5}	survival	rainbow trout	Giesy et al. (2002); Jones et al. (2001)
Metals and Butyltins					
Mercury	0.23	nr	survival	golden shiner	Webber and Haines (2003)
	nr	0.47	survival	mummichog	Matta et al.(2001)
Selenium	1.2[e]	1.6[f]	adverse effects	[national criterion]	EPA (2004)
TBT	0.018	0.159	growth	Japanese flounder	Shimasaki et al.(2003)
Organochlorine pesticides					
Total chlordane	0.71	nr	survival	goldfish	Moore et al.(Moore et al. 1977)
	nr	1.36	survival	goldfish	Feroz and Khan (1979)
Total DDT	1.80[g]	1.80[g]	survival	cutthroat trout	Allison et al.(1964)
Dieldrin	0.12	0.2	survival	rainbow trout	Shubat and Curtis (1986)
Endrin	0.00015[h]	0.0115	survival	largemouth bass	Fabacher (1976)
Endosulfan	0.00062[c]	0.031	survival	spot	Schimmel et al.(1977a)
Heptachlor	0.03[c]	1.5	survival	spot	Schimmel et al. (1976)
Heptachlor epoxide	0.08[h]	0.8	growth	bluegill	Andrews et al. (1966)

Analyte	NOAEL (mg/kg ww)	LOAEL (mg/kg ww)	Endpoint[A]	Test Species	Reference
gamma-BHC (lindane)	1.58[c]	79.0	survival	sheepshead minnow	Schimmel et al. (1977b)
Hexachlorobenzene	468	na	survival	fathead minnow	Schuytema et al.(1990)
Methoxychlor	0.050	0.300	growth	brook trout	Oladimeji and Leduc (1975)

[a] The NOAEL and/or LOAEL presented applies to all endpoints listed for a specific chemical.

[b] Tissue residues based on reported bioconcentration factor and water concentration.

[c] NOAEL estimated using an uncertainty factor of 50 (LC50 to NOAEL).

[d] LOAEL range was selected from this study because the specific LOAEL was unclear because of uncertainties associated with this study. The NOAEL range was estimated using an uncertainty factor of 5 (chronic LOAEL to NOAEL).

[e] National criterion for selenium in summer-collected fish. Dry weight concentration converted to wet weight assuming 80% moisture content.

[f] National criterion for selenium in winter-collected fish. Dry weight concentration converted to wet weight assuming 80% moisture content.

[g] The LOAEL is tissue concentration at 111 days (3.7 months) in fish exposed to 0.1 mg/L DDT in water where significant mortality occurred after approximately 4 months (approximately 120 days). The NOAEL (1,800 µg/kg ww) is the highest tissue concentration (at 466 days) in fish exposed to 0.03 mg/L DDT in water at which significant mortality did not occur over the entire exposure duration.

[h] NOAEL estimated using an uncertainty factor of 10 (acute/subchronic LOAEL to NOAEL).

na – not available; no LOAELs identified in the literature search; selected NOAEL is the highest unbounded NOAEL in the literature reviewed

nr – not relevant; NOAELs and LOAELs were derived from separate studies reporting the same endpoint

Table D-6. Studies selected to derive RBCs in prey items of fish

Analyte	NOAEL (mg/kg ww)	LOAEL (mg/kg ww)	Endpoint	Test Species	Reference
PAHs					
Benzo(a)pyrene	100	nr	growth	rainbow trout	Hart and Heddle (1991)
	nr	116	growth	English sole	Rice et al.(2000)
Total PAHs[c]	324	951	growth	chinook salmon	Meador et al. (2006)
Metals					
Arsenic	20	30	growth	rainbow trout	Oladimeji et al. (1984)
Cadmium	0.1[a]	0.5	growth	rockfish	Kim et al.(2004); Kang et al.(2005)
Chromium	9.42	na	growth	grey mullet	Walsh et al. (1994)
Copper	50	100	growth	rainbow trout	Kang et al.(2005)
Lead	7,040	na	growth	rainbow trout	Goettl et al.(1976)
Selenium	3.5	6.6	survival	bluegill juveniles	Cleveland et al.(1993)
Silver	3,000	na	growth	rainbow trout	Galvez and Wood (1999)
Vanadium	2.04[a]	10.2	growth	rainbow trout	Hilton and Bettger (1988)
Zinc	1,900	nr	growth	rainbow trout	Mount et al.(1994)
	nr	2,000	growth	rainbow trout	Takeda and Shimma (1977)

Note: Conversions to wet weight were based on type of food or prey species used in each study.

[a] NOAEL estimated using an uncertainty factor of 5 (chronic LOAEL to NOAEL).

na – not available; no LOAELs identified in the literature search; selected NOAEL is the highest unbounded NOAEL in the literature reviewed.

nr – not relevant; NOAEL and LOAELs were derived from separate studies reporting the same endpoint.

Table D-7. Studies selected to derive RBCs in prey items of birds

ANALYTE	NOAEL (MG/KG BW/DAY)	LOAEL (MG/KG BW/DAY)	ENDPOINT[A]	TEST SPECIES	REFERENCE
PAHs					
Benzo(a)pyrene	0.28[b]	1.4	reproduction	pigeon	Hough el al. (1993)
Total PAHs	8	40	growth	mallard	Patton and Dieter (1980)
Other SVOCs					
Bis(2-ethylhexyl) phthalate	65.8[c]	329	reproduction	chicken	Ishida et al.(1982)
PCBs and Dioxins					
PCBs	0.49	na	reproduction	screech owl	McLane and Hughes (1980)
	na	1.4	reproduction	ringed turtle dove	Peakall et al.(1972); Peakall and Peakall (1973)
2,3,7,8-TCDD	1.4×10^{-5}	1.4×10^{-4}	reproduction, survival	ring-necked pheasant	Nosek et al. (1992)
Metals and Butyltins					
Arsenic	10	40	reproduction	mallard	Stanley et al.(1994)
Cadmium	1.5	na	growth	chicken	Cain et al.(1983)
	na	4	growth	Japanese quail	Richardson et al.(1974)
Chromium	1	5	reproduction	black duck	Haseltine et al. (unpublished), as cited in (1996)
Cobalt	2.31[d]	23.1	growth	chicken	Diaz et al. (1994)
Copper	ns	29	growth	chicken	Smith (1969)
	21	ns	growth	chicken	Poupoulis and Jensen (1976)
Lead	ns	20	reproduction	Japanese quail	Edens et al.(1976)
	5.82	na	reproduction	American kestrel	Pattee (1984)
Mercury	0.018[b]	0.091	growth	great egret	Spalding et al.(2000)
Molybdenum	6.0[b]	30	reproduction	chicken	Lepore and Miller (1965)
Nickel	77	107	growth, survival	mallard	Cain and Pafford (1981)
Selenium	0.5	0.82	reproduction	mallard	Heinz et al.(1987)
Thallium	2.4[d]	24	survival	pheasant	Hudson et al. (1984)
Vanadium	1.2	2.3	growth	chicken	Ousterhout and Berg (1981)
Zinc	82	124	growth	chicken	Roberson and Schaible (1960)

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[A]	Test Species	Reference
Tributyltin	1.4	3.6	reproduction	Japanese quail	Coenen et al. (1992)
Organochlorine pesticides					
Aldrin	0.008[b]	0.04	survival	quail	DeWitt (1956)
Total chlordane	na	2	survival	bobwhite quail	Hill et al. (1975); Heath et al. (1972)
	0.6	na	growth, survival	bobwhite quail	Ludke (1976)
Total DDTs	0.064[e]	0.32	reproduction	mallard	Davison and Sell (1974)
Dieldrin	0.08	0.12	survival	quail	DeWitt (1956)
Endosulfan	10	na	reproduction	gray partridge	Abiola (1992)
Endrin	0.07	0.2	survival	quail	DeWitt (1956)
Hexachlorobenzene	na	1.2	reproduction	Japanese quail	Schwetz et al.(1974)
	1.1	na	reproduction	Japanese quail	Vos et al.(1971)
gamma-BHC (Lindane)	1.6	3.6	reproduction	Mallard	Chakravarty and Lahiri (1986); Chakravarty et al.(1986)
Heptachlor	0.5[d]	5.0	survival	bobwhite quail	Hill et al. (1975); Heath et al. (1972)
Methoxychlor	34.6	346	reproduction, survival	zebra finch	Gee et al. (2004); Millam et al. (2002)

[a] The NOAEL and/or LOAEL presented applies to all endpoints listed for a specific chemical

[b] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5

[c] There was a NOAEL of 1.45 mg/kg bw/day from a study that reported no effect on eggshell thinning, but this is an unbounded NOAEL at a substantially lower concentration than the study with observed effects. Therefore, the NOAEL was estimated from the reproductive LOAEL using an uncertainty factor of 5.

[d] NOAEL estimated from an acute or subchronic LOAEL using an uncertainty factor of 10.

[e] There was a NOAEL of 0.19 mg/kg bw/day from a study that reported no effect on eggshell thinning from exposure of barn owls to DDT (Mendenhall et al. 1983). However, there is evidence indicating that p,p'-DDE rather than DDT is the likely cause of eggshell thinning (Lundholm 1997). Therefore, the NOAEL was estimated from the DDE LOAEL for eggshell thinning using a factor of 5.

Table D-8. Studies selected to derive RBCs in prey items of mammals

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Reference
PAHs					
Benzo(a)pyrene	2.0[b]	10	reproduction	mouse	MacKenzie and Angevine (1981)
1-Methylnaphthalene	150	na	growth	mouse	Murata et al. (1993)
2-Methylnaphthalene	54	114	growth	mouse	Murata et al.(1997)
Naphthalene	133	na	growth, survival	mouse	Shopp et al. (1984)
Other SVOCs					
Butyl benzyl phthalate	250	750	growth, reproduction	rat	Tyl et al.(2004)
Bis(2-ethylhexyl)phthalate	44	91	reproduction	mouse	Tyl et al.(1988)
Diethyl phthalate	1,860	3,721	growth/reproduction	mouse	Lamb et al.(1987)
Di-n-butyl phthalate	16[b]	80	reproduction	rat	Wine et al.(1997)
Benzoic acid	80	na	growth, survival	rat	Ignat'ev (1965), as cited in IRIS (EPA 2006)
	na	750	growth	rat	Marquardt (1980)
Phenol	60	120	growth, reproduction	rat	Argus Research Laboratories (1997), as cited in IRIS (EPA 2006), Charles River Laboratories (1988) and NTP (1983), as cited in IRIS (EPA 2006)
PCBs and Dioxins					
PCBs	0.045[c]	0.089	reproduction	mink	Brunström et al.(2001)
2,3,7,8-TCDD	6.5×10^{-7}	4.9×10^{-6}	growth	guinea pig	DeCaprio et al. (1986)
Metals and Butlytins					
Antimony	1,489	na	growth	rat	Hext et al. (1999)
Arsenic	2.6	5.4	growth	rat	Byron et al.(1967)
Cadmium	3.5	13	growth	rat	Machemer and Lorke (1981)
Chromium	1,466	na	survival	rat	Ivankovic and Preussman (1975)
Cobalt	0.1	1.0	growth	rat	Chetty et al. (1979)
Copper	18	26	reproduction	mink	Aulerich et al. (1982)
Lead	11	90	reproduction	rat	Azar et al.(1973)

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Reference
Mercury	0.0017[b]	0.0084	growth	rat	Verschuuren et al.(1976)
Molybdenum	0.258[d]	2.58	reproduction, survival	mouse	Schroeder and Mitchener (1971)
Nickel	8.4	20	reproduction, growth	rat	Ambrose et al.(1976)
Selenium	0.055	0.08	growth	rat	Halverson et al.(1966)
Thallium	0.74	na	growth	rat	Formigli et al. (1986)
Vanadium	1.05	na	growth	mouse	Schroeder and Balassa (1967)
	na	2.7	growth	rat	Adachi et al. (2000)
Zinc	160	320	reproduction	rat	Schlicker and Cox (1968)
Tributyltin	0.4	2	reproduction	rat	Omura et al.(2001)
Dibutyltin	na	7.6	reproduction, growth	rat	Ema et al. (2003)
	3.8	na	growth	rat	Harazono and Ema (2003)
Organochlorine Pesticides					
Aldrin	0.83	4.1	survival	rat	Fitzhugh et al.(1964)
Chlordane	0.18	0.92	growth	mouse	Khasawinah and Grutsch (1989)
Total DDT	na	1.3	reproduction	mouse	Ware and Good (1967)
	1.2	na	reproduction	rat	Duby et al.(1971)
Dieldrin	0.038[b]	0.19	reproduction	mouse	Treon and Cleveland (1955)
Endosulfan	0.84	2.5	survival/ growth	mouse	Hack et al. (1995)
Endrin	0.4	ns	survival, growth	rat	Treon et al.(1955)
	na	0.92	survival, reproduction	mouse	Good and Ware (1969)
Heptachlor	1	1.8	survival/ growth/ reproduction	mink	Crum et al.(1993)
Hexachlorobenzene	0.026[b]	0.13	reproduction	mink/ferret	Bleavins et al.(1984)
gamma-BHC	64	na	growth	rat	Srinivasan et al.(1991)
beta-BHC	5.7	31	survival/ growth	rat	Van Velsen et al.(1986)
Methoxychlor	17	na	growth, reproduction	rat	Masutomi et al.(2003)
	na	56	growth, reproduction	rat	You et al.(2002)

na – NOAEL or LOAEL not available or not applicable based on the selection criteria discussed in Section D.2.4.

[a] The NOAEL and/or LOAEL presented applies to all endpoints listed for a specific chemical.

[b] NOAEL estimated from an chronic LOAEL using an uncertainty factor of 5.
[c] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 2.
[d] NOAEL estimated from an acute or subchronic LOAEL using an uncertainty factor of 10.

Table D-9. Body weights and daily food consumption values used to derive RBCs for birds and mammals

Receptor	Body Weight (kg)	Reference	Daily Food Consumption (kg ww/day)	Method and Reference
Female and male pigeon guillemot[a]	0.474	Storer (1952)	0.095	Estimated as 20% of body weight (Koelink 1972)
Female osprey	1.8	Poole (1989; as cited in Poole et al. 2002)	0.378	Estimated as 21% of body weight (Poole 1983; as cited in USEPA 1993)
Average male and female osprey	1.7		0.357	
Female river otter	7.9	Melquist and Hornocker (1983; as cited in EPA 1993)	1.32	Function of metabolic rate and caloric content of prey (Nagy 1987; as cited in EPA 1993)
Average male and female river otter	8.55		1.41	
Female harbor seal	76.5	Pitcher and Caulkins (1979; as cited in USEPA 1993)	2.40	Allometric equation for harbor seals (Boulva and McLaren 1979; as cited in USEPA 1993)
Average male and female harbor seal	80.6		2.50	

[a] Data on the difference between females and males were not available.

Table D-10. RBCs used to derive ACGs for fish and crab tissue

Fish or Crab Tissue	RBC Used to Derive ACG	
	Receptor-Specific Dietary RBC	Receptor-Specific Critical Tissue Residue RBC
Brown rockfish (whole body)	Osprey, river otter, harbor seal, humans	brown rockfish
English sole (whole body)	Brown rockfish, osprey, river otter, harbor seal, humans	English sole
English sole (fillet)	humans	na
Perch whole body	brown rockfish, osprey, pigeon guillemot, river otter, harbor seal, humans	na
Crab (edible meat)	Brown rockfish, pigeon guillemot, river otter, humans	crab
Shrimp and mussels	English sole, brown rockfish, pigeon guillemot, river otter, humans	na

na – not applicable

Table D-11. Comparison of Target Detection Limits and ACGs

Method and Analyte	Detection Limits[A] (mg/kg ww)		ACGs (mg/kg ww)[B]						Receptor and sample type with ACG lower than MDL
	MDL	RL	Brown Rockfish Whole Body	English sole Whole Body	English Sole Fillet	Perch Whole Body	Crab Edible Meat[C]	Shrimp and Mussels	
EPA Method 8270D									
PAHs									
Acenaphthene	0.017	0.067	5.0	5.0	5.0	5.0	5.0	5.0	
Acenaphthylene	0.015	0.067	na	na	na	na	na	na	
Anthracene	0.014	0.067	25	25	25	25	25	25	
Benzo(a)anthracene	0.016	0.067	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	humans – all tissue types
Benzo(a)pyrene	0.017	0.067	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	humans – all tissue types
Benzo(b)fluoranthene	0.027	0.067	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	humans – all tissue types
Benzo(k)fluoranthene	0.015	0.067	0.011	0.011	0.011	0.011	0.011	0.011	humans – all tissue types
Benzo(g,h,i)perylene	0.0010	0.067	na	na	na	na	na	na	
Chrysene	0.015	0.067	0.11	0.11	0.11	0.11	0.11	0.11	
Dibenzo(a,h)anthracene	0.014	0.067	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	humans – all tissue types
Dibenzofuran	0.015	0.067	0.084	0.084	0.084	0.084	0.084	0.084	
Fluoranthene	0.006	0.067	3.48	3.4	3.4	3.4	3.4	3.4	
Fluorene	0.018	0.067	3.4	3.4	3.4	3.4	3.4	3.4	
Indeno(1,2,3-cd)pyrene	0.012	0.067	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	humans – all tissue types
1-Methylnaphthalene	0.016	0.067	na	na	na	na	na	na	
2-Methylnaphthalene	0.016	0.067	0.34	0.34	0.34	0.34	0.34	0.34	
Naphthalene	0.015	0.067	1.7	1.7	1.7	1.7	1.7	1.7	
Phenanthrene	0.015	0.067	na	na	na	na	na	na	
Pyrene	0.013	0.067	2.5	2.5	2.5	2.5	2.5	2.5	
Total PAHs[d]	0.027	0.067	40	40	na	40	40	40	
Other SVOCs									

Method and Analyte	Detection Limits[A] (mg/kg ww)		ACGs (mg/kg ww)[B]						Receptor and sample type with ACG lower than MDL
	MDL	RL	Brown Rockfish Whole Body	English sole Whole Body	English Sole Fillet	Perch Whole Body	Crab Edible Meat[C]	Shrimp and Mussels	
1,2,4-Trichlorobenzene	0.016	0.067	0.84	0.84	0.84	0.84	0.84	0.84	
1,2-Dichlorobenzene	0.018	0.067	7.6	7.6	7.6	7.6	7.6	7.6	
1,3-Dichlorobenzene	0.016	0.067	0.25	0.25	0.25	0.25	0.25	0.25	
1,4-Dichlorobenzene	0.014	0.067	0.034	0.034	0.034	0.034	0.034	0.034	humans – all tissue types
2,4,5-Trichlorophenol	0.065	0.33	8.4	8.4	8.4	8.4	8.4	8.4	
2,4,6-Trichlorophenol	0.065	0.33	0.073	0.073	0.073	0.073	0.073	0.073	humans – all tissue types
2,4-Dichlorophenol	0.12	0.33	0.25	0.25	0.25	0.25	0.25	0.25	humans – all tissue types
2,4-Dimethylphenol	0.031	0.067	1.7	1.7	1.7	1.7	1.7	1.7	
2,4-Dinitrophenol	0.11	0.67	0.17	0.17	0.17	0.17	0.17	0.17	humans – all tissue types
2,4-Dinitrotoluene	0.10	0.33	0.17	0.17	0.17	0.17	0.17	0.17	humans – all tissue types
2,6-Dinitrotoluene	**0.11**	0.33	0.084	0.084	0.084	0.084	0.084	0.084	humans – all tissue types
2-Chloronaphthalene	0.014	0.067	6.7	6.7	6.7	6.7	6.7	6.7	
2-Chlorophenol	0.012	0.067	0.42	0.42	0.42	0.42	0.42	0.42	
2-Methylphenol	0.023	0.067	4.2	4.2	4.2	4.2	4.2	4.2	
3,3'-Dichlorobenzidine	**0.21**	0.33	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	humans – all tissue types
4-Chloroaniline	0.20	0.33	0.34	0.34	0.34	0.34	0.34	0.34	
4-Methylphenol	0.033	0.067	0.42	0.42	0.42	0.42	0.42	0.42	
4-Nitrophenol	0.10	0.33	na	na	na	na	na	na	
Aniline	0.067	0.067	0.14	0.14	0.14	0.14	0.14	0.14	
Benzidine	**0.067**	0.67	3.5×10^{-6}	3.5×10^{-6}	3.5×10^{-6}	3.5×10^{-6}	3.5×10^{-6}	3.5×10^{-6}	humans – all tissue types
Benzoic acid	0.17	0.67	3.4	3.4	340	340	340	340	
Benzyl alcohol	0.15	0.33	42	42	42	42	42	42	
bis(2-chloroethyl)ether	**0.015**	0.067	0.00073	0.00073	0.00073	0.00073	0.00073	0.00073	humans – all tissue types
bis(2-ethylhexyl)phthalate	0.027	0.067	0.058	0.058	0.058	0.058	0.058	0.058	
bis-chloroisopropyl ether	0.015	0.067	0.00073	0.00073	0.00073	0.00073	0.00073	0.00073	humans – all tissue types

Method and Analyte	Detection Limits[A] (mg/kg ww)		ACGs (mg/kg ww)[B]						Receptor and sample type with ACG lower than MDL
	MDL	RL	Brown Rockfish Whole Body	English sole Whole Body	English Sole Fillet	Perch Whole Body	Crab Edible Meat[C]	Shrimp and Mussels	
Butyl benzyl phthalate	0.0077	0.067	6.45	6.45	17	17	17	17	
Carbazole	0.0077	0.067	0.040	0.040	0.040	0.040	0.040	0.040	humans – all tissue types
Di-ethyl phthalate	0.020	0.067	1.10	1.10	67	67	67	67	
Dimethyl phthalate	0.017	0.067	0.498	0.498	na	na	na	na	
Di-n-butyl phthalate	0.0071	0.067	1.17	1.17	8.4	8.4	8.4	8.4	
Hexachlorobutadiene	0.015	0.067	0.010	0.010	0.010	0.010	0.010	0.010	humans – all tissue types
Hexachloroethane	0.016	0.067	0.058	0.058	0.058	0.058	0.058	0.058	
Isophorone	0.018	0.067	0.85	0.85	0.85	0.85	0.85	0.85	
Nitrobenzene	0.014	0.067	0.048	0.048	0.048	0.048	0.048	0.048	humans – all tissue types
N-Nitrosodimethylamine	**0.086**	0.33	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	humans – all tissue types
N-Nitrosodi-n-propylamine	**0.067**	0.33	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	humans – all tissue types
N-Nitrosodiphenylamine	0.016	0.067	0.16	0.16	0.16	0.16	0.16	0.16	
Pentachlorophenol	**0.17**	0.33	0.0067	0.0067	0.0067	0.0067	0.0067	0.0067	humans – all tissue types
Phenol	0.033	0.067	1.47	1.47	25	25	25	25	
EPA Method 8082									
Aroclor 1016	0.0029	0.020	0.012	0.012	0.012	0.012	0.012	0.012	humans – all tissue types
Aroclor 1221	0.0029	0.020	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	humans – all tissue types
Aroclor 1232	0.0029	0.020	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	humans – all tissue types
Aroclor 1242	0.0039	0.020	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	humans – all tissue types
Aroclor 1248	0.0039	0.020	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	humans – all tissue types
Aroclor 1254	0.0039	0.020	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	humans – all tissue types
Aroclor 1260	0.0039	0.020	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	humans – all tissue types
Total PCBs[d]	0.0039	0.020	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	humans – all tissue types
EPA Method 1613B									
Dioxin and furan congeners[e]	1.2×10^{-7}	5.0×10^{-7}	8×10^{-9}	8×10^{-9}	8×10^{-9}	8×10^{-9}	8×10^{-9}	8×10^{-9}	humans – all tissue types

Method and Analyte	Detection Limits[A] (mg/kg ww)		ACGs (mg/kg ww)[B]						Receptor and sample type with ACG lower than MDL
	MDL	RL	Brown Rockfish Whole Body	English sole Whole Body	English Sole Fillet	Perch Whole Body	Crab Edible Meat[C]	Shrimp and Mussels	
EPA Method 1668A									
PCB congeners[e]	1.78×10^{-6}	1.00×10^{-6}	2.4×10^{-6}	2.4×10^{-6}	2.4×10^{-6}	2.4×10^{-6}	2.4×10^{-6}	2.4×10^{-6}	
EPA Method 6020, 6010B, or 7000									
Antimony	0.02	0.04	0.034	0.034	0.034	0.034	0.034	0.034	humans – all tissue types
Arsenic	0.009	0.02	0.00054	0.00054	0.00054	0.00054	0.00054	0.00054	humans – all tissue types
Cadmium	0.004	0.04	0.084	0.084	0.084	0.084	0.084	0.084	
Chromium	0.06	0.1	0.25	0.25	0.25	0.25	0.25	0.25	
Cobalt	0.008	0.2	3.2	3.2	na	3.2	12	12	
Copper	0.058	0.5	3.4	3.4	3.4	3.4	3.4	3.4	
Lead	0.078	1.0	30	30	29	29	29	29	
Molybdenum	0.008	0.2	0.42	0.42	0.42	0.42	0.42	0.42	
Nickel	0.11	0.5	1.7	1.7	1.7	1.7	1.7	1.7	
Selenium	0.028	0.04	0.33	0.33	0.42	0.33	0.33	0.33	
Silver	0.006	0.2	0.42	0.42	0.42	0.42	0.42	0.42	
Thallium	0.011	0.02	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	humans – all tissue types
Vanadium	0.034	0.2	0.084	0.084	0.084	0.084	0.084	0.084	
Zinc	0.44	4.0	25	25	25	25	25	25	
EPA Method 1632									
Inorganic arsenic	0.003	0.03	0.00054	0.00054	0.00054	0.00054	0.00054	0.00054	humans – all tissue types
EPA Method 7471A									
Mercury	0.005	0.01	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	humans – all tissue types; pigeon guillemot – perch, crab, shrimp and mussels
TBT Method - Krone 1989									
Di-n-butyltin	0.0039	0.012	23	23	23	23	23	23	

Method and Analyte	Detection Limits[A] (mg/kg ww)		ACGs (mg/kg ww)[B]						Receptor and sample type with ACG lower than MDL
	MDL	RL	Brown Rockfish Whole Body	English sole Whole Body	English Sole Fillet	Perch Whole Body	Crab Edible Meat[C]	Shrimp and Mussels	
Tri-n-butyltin	0.0034	0.0080	0.018	0.018	0.025	0.025	0.025	0.025	
EPA Method 8081A									
4,4'-DDD	0.015	0.020	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	humans – all tissue types
4,4'-DDE	0.012	0.020	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	humans – all tissue types
4,4'-DDT	0.013	0.020	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	humans – all tissue types
Total DDT	0.015	0.020	0.32	0.32	na	0.32	0.046	0.32	
Aldrin	0.0057	0.010	4.8×10^{-5}	4.8×10^{-5}	4.8×10^{-5}	4.8×10^{-5}	4.8×10^{-5}	4.8×10^{-5}	humans – all tissue types
alpha-BHC	0.0048	0.010	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013	humans – all tissue types
beta-BHC	0.0039	0.010	0.00045	0.00045	0.00045	0.00045	0.00045	0.00045	humans – all tissue types
Total chlordane[d]	0.060	0.010	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	humans – all tissue types
Dieldrin	0.012	0.020	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	humans – all tissue types
Endosulfan	0.011	0.020	0.00062	0.00062	0.50	0.50	0.50	0.50	Rockfish – whole body rockfish; English sole – whole body English sole
Endosulfan sulfate	0.013	0.020	na	na	na	na	na	na	
Endrin	0.015	0.020	0.0012	0.0012	0.025	0.025	0.025	0.025	Rockfish – whole body rockfish; English sole – whole body English sole
gamma-BHC (Lindane)	0.0050	0.010	0.00062	0.00062	0.00062	0.00062	0.00062	0.00062	humans – all tissue types
Heptachlor	0.0056	0.010	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	humans – all tissue types
Heptachlor epoxide	0.0051	0.010	0.000089	0.000089	0.000089	0.000089	0.000089	0.000089	humans – all tissue types
Hexachlorobenzene	0.0042	0.010	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	humans – all tissue types
Methoxychlor	0.063	0.010	0.05	0.05	0.42	0.42	0.015	0.42	
Mirex	0.020	0.020	0.017	0.017	0.017	0.017	0.017	0.017	humans – all tissue types
Toxaphene	1.0	1.0	0.00073	0.00073	0.00073	0.00073	0.00073	0.00073	humans – all tissue types

Note: Actual RLs and MDLs will vary based on the amount of sample volume used for each analysis, matrix interferences, and the analytical dilution.

MDLs and RLs in **bold** exceed an ACG.

[a] RLs and MDLs from Analytical Resources, Inc, Brooks Rand, and Analytical Perspectives

[b] ACGs for each tissue type are the lowest of the dietary or critical tissue residue RBCs associated with that tissue type.

[c] ACG for edible meat tissue samples. Human ingestion rate of hepatopancreas is not available, but is expected to be lower than the ingestion rate of crab edible meat. Therefore, ACGs for hepatopancreas would be higher, so the chemicals with ACGs lower than the RL and MDL presented in the last column would not be affected.

[d] RLs and MDLs for calculated totals are the highest of the RLs and MDLs for the individual components.

[e] Dioxin-like PCB congeners and dioxin and furan congeners will be evaluated as 2,3,7,8-TCDD toxic equivalents (TEQs) in the risk assessments, rather than as individual congeners. Thus, ACGs for PCB and dioxin and furan TEQs are presented. Because risks will be assessed based on sums of these congeners (normalized per their relative toxicity to TCDD), the comparison to MDLs on a congener-specific basis is somewhat uncertain. MDLs and RLs presented are for PCB 126 and 2,3,7,8-TCDD.

ACG – analytical concentration goal

MDL – method detection limit

RL – reporting limit

na – not available

nd – not determined

Table D-12. Tissue mass required for each analysis

ANALYTE	METHOD	TISSUE MASS (G)
PCB congeners	EPA 1668	25
Dioxin/furans	EPA 1613	25
PCB Aroclors	EPA 8082	30
SVOCs (including PAHs, and phthalates)	EPA 8270D	30
Organochlorine pesticides	EPA 8081A	25
Organochlorine pesticides confirmation[a]	EPA 1699 (modified)	25
Inorganic arsenic	EPA 1632	5
Mercury	EPA 7471A	2
Other metals[b]	EPA 6010B or EPA 6020	3
Tributyltin	Krone et al., 1989	20
lipids	NOAA 1997	5
total solids	PSEP 2007	5
Total Mass		200

[a] a subset of samples will be submitted for MS/MS analysis of pesticides

[b] antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, vanadium, zinc

D.6.0 References

Abiola FA. 1992. Ecotoxicity of organochloride insecticides: effects of endosulfan on bird reproduction and evaluation of its induction effect in partridge (*Perdix perdix* L.). Rev Med Vet 143(5):443-450.

Adachi A, Asai K, Koyama Y, Matsumoto Y, Okano T. 2000. Subacute vanadium toxicity in rats. J Health Sci 46(6):503-508.

Allison DT, Kollman BJ, Cope OB, Van Valin C. 1964. Some chronic effects of DDT on cutthroat trout. Research report 64. Bureau of Sport Fisheries and Wildlife, US Fish and Wildlife Service, Washington, DC.

Ambrose AM, Larson PS, Borzelleca JF, Hennigar Jr GR. 1976. Long term toxicologic assessment of nickel in rats and dogs. J Food Sci Technol 13(4):181-187.

Andrews AK, Van Valin CC, Stebbings BE. 1966. Some effects of heptachlor on bluegills. Trans Am Fish Soc 95:297-309.

Armstrong DA, Buchanan DV, Mallon MH, Caldwell RS, Millemann RE. 1976. Toxicity of the insecticide methoxychlor to the dungeness crab *Cancer magister*. Mar Biol 38:239-252.

Aulerich RJ, Ringer RK, Bleavins MR, Napolitano A. 1982. Effects of supplemental dietary copper on growth, reproductive performance and kit survival of

standard dark mink and the acute toxicity of copper to mink. J Anim Sci 55(2):337-343.
Azar A, Trochimowicz HJ, Maxfield ME. 1973. Review of lead studies in animals carried out at Haskell Laboratory-two-year feeding study and response to hemorrhage study. In: Barth D, ed, Environmental Health Aspects of Lead, International Symposium, Amsterdam, the Netherlands. Commission of European Communities, pp 199-210.
Barrows ME, Petrocelli SR, Macek KJ, Carroll JR. 1980. Bioconcentration and elimination of selected water pollutants by bluegill sunfish (*Lepomis macrochirus*). In: Haque R, ed, Dynamics, exposure and hazard assessment of toxic chemicals. Ann Arbor Science Publishers, Ann Arbor, MI.
Bianchini A, Gilles R. 1996. Toxicity and accumulation of mercury in three species of crabs with different osmoregulatory capacities. Bull Environ Contam Toxicol 57:91-98.
Bleavins MR, Aulerich RJ, Ringer RK. 1984. Effects of chronic dietary hexachlorobenzene exposure on the reproductive performance and survivability of mink and European ferrets. Arch Environ Contam Toxicol 13:357-365.
Boulva J, McLaren IA. 1979. Biology of the harbor seal, *Phoca vitulina*, in eastern Canada. Fish Res Board Can Bulletin 200:1-24.
Brunström B, Lund BE, Bergman A, Asplund L, Athanassiadis I, Athanasiadou M, Jensen S, Örberg J. 2001. Reproductive toxicity in mink (*Mustela vison*) chronically exposed to environmentally relevant polychlorinated biphenyl concentrations. Environ Toxicol Chem 20(10):2318-2327.
Byron WR, Bierbower GW, Brouwer JB, Hansen WH. 1967. Pathologic changes in rats and dogs from two-year feeding of sodium arsenite or sodium arsenate. Toxicol Appl Pharmacol 10:132-147.
Cain BW, Pafford EA. 1981. Effects of dietary nickel on survival and growth of mallard ducklings. Arch Environ Contam Toxicol 10:737-745.
Cain BW, Sileo L, Franson JC, Moore J. 1983. Effects of dietary cadmium on mallard ducklings. Environ Res 32:286-297.
Calabrese EJ, Baldwin LA. 1993. Performing ecological risk assessments. Lewis Publishers, Chelsea, MI.
Canli M, Furness RW. 1995. Mercury and cadmium uptake from seawater and from food by the Norway lobster *Nephrops norvegicus*. Environ Toxicol Chem 14(5):819-828.
Chakravarty S, Lahiri P. 1986. Effect of lindane on eggshell characteristics and calcium level in the domestic duck. Toxicology 42:245-258.
Chakravarty S, Mandal A, Lahiri P. 1986. Effect of lindane on clutch size and level of egg yolk protein in domestic duck. Toxicology 39:93-103.
Chetty KY, Rau S, Drummond L, Desaiah D. 1979. Cobalt induced changes in immune response and adenosine triphosphatase activities in rats. J Environ Sci Health B14(5):525-544.

Cleveland L, Little EE, Buckler DR, Wiedmeyer RH. 1993. Toxicity and bioaccumulation of waterborne and dietary selenium in juvenile bluegill (*Lepomis macrochirus*). Aquat Toxicol 27:265-280.

Coenen TMM, Brouwer A, Enninga IC, Koeman JH. 1992. Subchronic toxicity and reproduction effects if tri-n-butyltin oxide in Japanese quail. Arch Environ Contam Toxicol 23:457-463.

Crum JA, Bursian SJ, Aulerich RJ, Polin D, Braselton WE. 1993. The reproductive effects of dietary heptachlor in mink (*Mustela vison*). Arch Environ Contam Toxicol 24:156-164.

Davison KL, Sell JL. 1974. DDT thins shells of eggs from mallard ducks maintained on *ad libitum* or controlled-feeding regimens. Arch Environ Contam Toxicol 2(3):222-232.

DeCaprio AP, McMartin DN, O'Keefe PW, Rej R, Silkworth JB, Kaminsky LS. 1986. Subchronic oral toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in the guinea pig: comparisons with a PCB-containing transformer fluid pyrolysate. Fund Appl Toxicol 6:454-463.

DeWitt JB. 1956. Chronic toxicity to quail and pheasants of some chlorinated insecticides. Agric Food Chem 4(10):863-866.

Diaz GJ, Julian RJ, Squires EJ. 1994. Lesions in broiler chickens following experimental intoxication with cobalt. Avian Dis 38(2):308-316.

Duby RT, Travis HF, Terrill CE. 1971. Uterotropic activity of DDT in rats and mink and its influence on reproduction in the rat. Toxicol Appl Pharmacol 18:348-355.

Edens FW, Garlich JD. 1983. Lead-induced egg production decrease in leghorn and Japanese quail hens. Poult Sci 62:1757-1763.

Edens FW, Benton E, Bursian SJ, Morgan GW. 1976. Effect of dietary lead on reproductive performance in Japanese quail, *Coturnix coturnix japonica*. Toxicol Appl Pharmacol 38:307-314.

Ema M, Harazono A, Hirose A, Kamata E. 2003. Protective effects of progesterone on implantation failure induced by dibutyltin dichloride in rats. Toxicol Let 143:233-238.

EPA. 1993. Wildlife exposure factors handbook. EPA/600/R-93/187a. Office of Research and Development, US Environmental Protection Agency, Washington, DC.

EPA. 1997. EPA Region 10 supplemental ecological risk assessment guidance for Superfund. EPA/910/R-97/005. Region 10 Office of Environmental Assessment Risk Evaluation Unit, US Environmental Protection Agency, Seattle, WA.

EPA. 2004. USEPA contract laboratory program national functional guidelines for inorganic data review. EPA 540-R-04-004. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 2006. Integrated Risk Information System (IRIS) database [online]. US Environmental Protection Agency, Washington, DC. [Cited 1/2006.] Available from: http://www.epa.gov/iris/.

Evans ML. 1980. Copper accumulation in the crayfish (*Orconectes rusticus*). Bull Environ Contam Toxicol 24:916-920.
Fabacher DL. 1976. Toxicity of endrin and an endrin-methyl parathion fomulation to largemouth bass fingerlings. Bull Environ Contam Toxicol 16(3):376-378.
Feroz M, Khan MAQ. 1979. Fate of ^{14}C-cis-chlordane in goldfish, *Carassius auratus* (L.). Bull Environ Contam Toxicol 23:64-69.
Fitzhugh OG, Nelson AA, Quaife ML. 1964. Chronic oral toxicity of aldrin and dieldrin in rats and dogs. Food Chem Toxicol 2:551-562.
Formigli L, Scelsi R, Poggi P, Gregotti C, Di Nucci A, Sabbioni E, Gottardi L, Manzo L. 1986. Thallium-induced testicular toxicity in the rat. Environ Res 40:531-539.
Galvez F, Wood CM. 1999. Physiological effects of dietary silver sulfide exposure in rainbow trout. Environ Toxicol Chem 18(1):84-88.
Gee JM, Craig-Veit CB, Millam JR. 2004. Posthatch methoxychlor exposure adversely affects reproduction of adult zebra finches, *Taeniopygia guttata*. Bull Environ Contam Toxicol 73:607-612.
Giesy JP, Jones PD, Kannan K, Newsted JL, Tillitt DE, Williams LL. 2002. Effects of chronic dietary exposure to environmentally relevant concentrations if 2,3,7,8-tetrachlorodibenzo-p-dioxin on survival, growth, reproduction and biochemical responses of female rainbow trout (*Oncorhynchus mykiss*). Aquat Toxicol 59:35-53.
Goettl JP, Davies PH, Sinley JR. 1976. Water pollution studies. Colorado Fisheries Research Review 1972-1975. CO Div Wildlife Rev 8:68-75.
Good EE, Ware GW. 1969. Effects of insecticides on reproduction in the laboratory mouse. IV. Endrin and dieldrin. Toxicol Appl Pharmacol 14:201-203.
Gries TH. 2008. Personal communication (e-mail to Debra Williston, King County, regarding PSAMP 2007 dioxin and furan data). Washington Department of Ecology, Lacey, WA. May 15, 2008.
Hack R, Ebert E, Leist KH. 1995. Chronic toxicity and carcinogenicity studies with the insecticide endosulfan in rats and mice. Food Chem Toxicol 33(11):941-950.
Halverson AW, Palmer IS, Guss PL. 1966. Toxicity of selenium to post-weanling rats. Toxicol Appl Pharmacol 9:477-484.
Hansen DJ, Parrish PR, Forester J. 1974. Aroclor 1016: Toxicity to and uptake by estuarine animals. Environ Res 7:363-373.
Harazono A, Ema M. 2003. Suppression of decidual cell resonse induced by dibutyltin dichloride in pseudopregnant rats: as a cause of early embryonic loss. Reprod Toxicol 17:393-399.
Hart DR, Heddle JA. 1991. Micronucleus assays in peripheral blood of rainbow trout: Timing of response and chemical mutagen sensitivity. Can Tech Rep Fish Aquat Sci 1774(2):993-1010.
Heath RG, Spann JW, Hill EF, Kreitzer JF. 1972. Comparative dietary toxicities of pesticides to birds. Wildlife no. 152. Patuxent Wildlife Research Center, Bureau of Sport Fisheries and Wildlife, Laurel, MD.

Heinz GH, Hoffman DJ, Krynitsky AJ, Weller DMG. 1987. Reproduction in mallards fed selenium. Environ Toxicol Chem 6:423-433.
Hext PM, Pinto PJ, Rimmel BA. 1999. Subchronic feeding study of antimony trioxide in rats. J Appl Toxicol 19:205-209.
Hill EF, Heath RG, Spann JW, Williams JD. 1975. Lethal dietary toxicities of environmental pollutants to birds. US Fish and Wildlife Service, Laurel, MD.
Hilton JW, Bettger WJ. 1988. Dietary vanadium toxicity in juvenile rainbow trout: a preliminary study. Aquat Toxicol 12:63-71.
Hough JL, Baird MB, Sfeir GT, Pacini CS, Darrow D, Wheelock C. 1993. Benzo(a)pyrene enhances atherosclerosis in white carneau and show racer pigeons. Arterioscler Thromb 13:1721-1727.
Hudson RH, Tucker RK, Haegele MA. 1984. Handbook of toxicity of pesticides to wildlife. Resource publication 153. 2nd ed. US Fish and Wildlife Service, Washington, DC.
Hugla JL, Thome JP. 1999. Effects of polychlorinated biphenyls on liver ultrastructure, hepatic monooxygenases, and reproductive success in the barbel. Ecotoxicol Environ Saf 42:265-273.
Ishida M, Suyama K, Adachi S, Hoshino T. 1982. Distribution of orally administered di-ethylhexyl phthalate in laying hens. Poult Sci 61:262-267.
Ivankovic S, Preussman R. 1975. Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in subacute and long-term feeding experiments in rats. Food Cosmet Toxicol 13:347-351.
Jarvinen AW, Ankley GT. 1999. Linkage of effects to tissue residues: Development of a comprehensive database for aquatic organisms exposed to inorganic and organic chemicals. SEATAC Press, Pensacola, FL.
Johnson BT, Saunders CR, Sanders HO. 1971. Biological magnification and degradation of DDT and aldrin by freshwater invertebrates. J Fish Res Bd Can 28:705-709.
Jones PD, Kannan K, Newsted JL, Tillitt DE, Williams LL, Giesy JP. 2001. Accumulation of 2,3,7,8-tetrachlorodibenzo-p-dioxin by rainbow trout (*Oncorhynchus mykiss*) at environmentally relevant dietary concentrations. Environ Toxicol Chem 20(2):344-350.
Kaiser KLE, Dixon DG, Hodson PV. 1984. QSAR studies on chlorophenols, chlorobenzenes and para-substituted phenols. In: Kaiser KLE, ed, QSAR in environmental toxicology. D. Reidel Publishing Co., Dordrecht, the Netherlands, pp 189-206.
Kang J-C, Kim S-G, Jang S-W. 2005. Growth and hematological changes of rockfish, *Sebastes schlegeli* (Hilgendorf) exposed to dietary Cu and Cd. J World Aquacult Soc 36(2):188-195.
Khasawinah AM, Grutsch JF. 1989. Chlordane: 24-month tumorigenicity and chronic toxicity test in mice. Reg Toxicol Pharmacol 10:244-254.

Kim S-G, Kim J-W, Kang J-C. 2004. Effect of dietary cadmium on growth and haematological parameters of juvenile rockfish, *Sebastes schlegeli* (Hilgendorf). Aquacult Res 35:80-86.

Koelink AF. 1972. Bioenergetics of growth in the pigeon guillemot *Cepphus columba*. M.Sc. thesis. University of British Columbia, Vancouver, BC.

Lamb JC, Chapin RE, Teague J, Lawton AD, Reel JR. 1987. Reproductive effects of four phthalic acid esters in the mouse. Toxicol Appl Pharmacol 88:255-269.

Lepore PD, Miller RF. 1965. Embryonic viability as influenced by excess molybdenum in chicken breeder diets. Proc Soc Exper Biol Med 118:155-157.

Lindsay DM, Sanders JG. 1990. Arsenic uptake and transfer in a simplified estuarine food chain. Environ Toxicol Chem 9:391-395.

Lu P-Y, Metcalf RL. 1975. Environmental fate and biodegradability of benzene derivatives as studied in a model aquatic ecosystem. Environ Health Perspect 10:268-284.

Ludke JL. 1976. Organochlorine pesticide residues associated with mortality: additivity of chlordane and endrin. Bull Environ Contam Toxicol 16:253-260.

Machemer L, Lorke D. 1981. Embryotoxic effect of cadmium on rats upon oral administration. Toxicol Appl Pharmacol 58:438-443.

MacKenzie KM, Angevine DM. 1981. Infertility in mice exposed *in utero* to benzo(a)pyrene. Biol Reprod 24:183-191.

Masutomi N, Shibutani M, Takagi H, Uneyama C, Takahashi N, Hirose M. 2003. Impact of dietary exposure to methoxychlor, genestein, or diisononyl phthalate during the perinatal period on the development of the rat endocrine/reproductive systems in later life. Toxicology 192:149-170.

Matta MB, Linse J, Cairncross C, Francendese L, Kocan RM. 2001. Reproductive and transgenerational effects of methylmercury or Aroclor 1268 on *Fundulus heteroclitus*. Environ Toxicol Chem 20(2):327-335.

McKim JM, Schmeider PK. 1990. Bioaccumulation: does it reflect toxicity? In: Nagel R, Loskill R, eds, Bioaccumulation in aquatic systems: Contributions to the assessment. Proceedings, International Workshop, Berlin, 1990. VCG Publishers, New York, NY, pp 161-188.

McLane MAR, Hughes DL. 1980. Reproductive success of screech owls fed Aroclor 1248. Arch Environ Contam Toxicol 9:661-665.

Meador JP, Sommers FC, Ylitalo GM, Sloan CA. 2006. Altered growth and related physiological responses in juvenile chinook salmon (*Oncorhynchus tshawytscha*) from dietary exposure to polycyclic aromatic hydrocarbons (PAHs). Can J Fish Aquat Sci 63:2364-2376.

Mehrle PM, Mayer FL. 1976. Di-2-ethylhexyl phthalate: residue dynamics and biological effects in rainbow trout and fathead minnows. Proceedings of University of Missouri's 10th Annual Conference on Trace Substances in Environmental Health, June 8-10, Columbia, MO, pp 519-524.

Melquist WE, Hornocker MG. 1983. Ecology of river otters in west central Idaho. In: Kirkpatrick RL, ed, Wildlife monographs. Vol 83. The Wildlife Society, Bethesda, MD, p 60.

Millam JR, Craig-Veit CB, Batchelder ME, Viant MR, Herbeck TM, Woods LW. 2002. An avian bioassay for environmental estrogens: the growth response of zebra finch (*Taeniopygia guttata*) chick oviduct to oral estrogens. Environ Toxicol Chem 21(12):2663-2668.

Miramand P, Guary JC, Fowler SW. 1981. Uptake, assimilation, and excretion of vanadium in the shrimp, *Lysmata seticaudata* (Risso), and the crab, *Carcinus maenas* (L.). J Exp Mar Biol Ecol 49:267-287.

Mirenda RJ. 1986. Acute toxicity and accumulation of zinc in the crayfish, *Orconectes virilis* (Hagen). Bull Environ Contam Toxicol 37:387-394.

Moore R, Toro E, Stanton M, Khan MAQ. 1977. Absorption and elimination of ^{14}C-*alpha*- and *gamma*-chlordane by a freshwater alga, daphnid, and goldfish. Arch Environ Contam Toxicol 6:411-420.

Mortimer MR, Miller GJ. 1994. Susceptibility of larval and juvenile instars of the sand crab, *Portunus pelagicus* (L.) to sea water contaminated by chromium, nickel or copper. Aust J Mar Freshwater Res 45:1107-1121.

Mount DR, Barth AK, Garrison TD, Barten KA, Hockett JR. 1994. Dietary and waterborne exposure of rainbow trout (*Oncorhynchus mykiss*) to copper, cadmium, lead and zinc using a live diet. Environ Toxicol Chem 13(12):2031-41.

Murata Y, Denda A, Maruyama H, Konishi Y. 1993. Chronic toxicity and carcinogenicity studies of 1-methylnaphthalene in $B6C3F_1$ mice. Fund Appl Toxicol 21:44-51.

Murata Y, Denda A, Maruyama H, Nakae D, Tsutsumi M, Tsujiuchi T, Konishi Y. 1997. Chronic toxicity and carcinogenicity studies of 2-methylnaphthalene in $B6C3F_1$ mice. Fund Appl Toxicol 36:90-93.

Nagy KA. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecol Monogr 57(2):111-128.

Nimmo DR, Wilson Jr AJ, Blackman RR. 1970. Localization of DDT in the body organs of pink and white shrimp. Bull Environ Contam Toxicol 5(4):333-341.

Nosek JA, Craven SR, Sullivan JR, Hurley SS, Peterson RE. 1992. Toxicity and reproductive effects of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in ring-necked pheasant hens. J Toxicol Environ Health 35:187-198.

Oladimeji AA, Leduc G. 1975. Effects of dietary methoxychlor on the food maintenance requirements of brook trout. Progr Wat Tech 7(3/4):587-598.

Oladimeji AA, Qadri SU, DeFreitas ASW. 1984. Long-term effects of arsenic accumulation in rainbow trout, *Salmo gairdneri*. Bull Environ Contam Toxicol 32:732-741.

Omura M, Ogata R, Kubo K, Shimasaki Y, Aou S, Oshima Y, Tanaka A, Hirata M, Makita Y, Inoue N. 2001. Two-generation reproductive toxicity study ot tributyltin chloride in male rats. Toxicol Sci 64:224-232.

Ousterhout LE, Berg LR. 1981. Effects of diet composition on vanadium toxicity in laying hens. Poult Sci 60:1152-1159.
Parrish PR, Schimmel SC, Hansen DJ, Patrick Jr JM, Forester J. 1976. Chlordane: effects on several estuarine organisms. J Toxicol Environ Health 1:485-494.
Pattee OH. 1984. Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. Arch Environ Contam Toxicol 13:29-34.
Patton JF, Dieter MP. 1980. Effects of petroleum hydrocarbons on hepatic function in the duck. Comp Biochem Physiol 65C:33-36.
Peakall DB, Peakall ML. 1973. Effect of a polychlorinated biphenyl on the reproduction of artificially and naturally incubated dove eggs. J Appl Ecol 10(3):863-868.
Peakall DB, Lincer JL, Bloom SE. 1972. Embryonic mortality and chromosomal alterations caused by Aroclor 1254 in ring doves. Environ Health Perspect 1:103-104.
Pitcher KW, Calkins OG. 1979. Biology of the harbor seal, Phoca vitulina richardsi, in the Gulf of Alaska. Final. Outer Continental Shelf Environmental Assessment Program Research Unit 229. Bureau of Land Management, US Department of the Interior, Washington, DC.
Poole A. 1989. Ospreys: a natural and unnatural history. Cambridge University Press, Cambridge, UK.
Poole AF. 1983. Courtship feeding, clutch size, and egg size in ospreys: a preliminary report. In: Bird DM, Seymour NR, Gerrard JM, eds, Biology and management of bald eagles and ospreys. Harpell Press, St. Anne de Bellvue, Quebec, pp 243-256.
Poole AF, Bierregaard RO, Martell MS. 2002. Osprey (*Pandion haliaetus*) [online]. In: Poole A, ed. The birds of North America online. Cornell Laboratory of Ornithology, Ithaca, NY. Available from: http://bna.birds.cornell.edu/bna/species/683.
Poupoulis C, Jensen LS. 1976. Effect of high dietary copper on gizzard integrity of the chick. Poult Sci 55:113-121.
Rice CA, Myers MS, Willis ML, French BL, Casillas E. 2000. From sediment bioassay to fish biomarker – connecting the dots using simple trophic relationships. Mar Environ Res 50:527-533.
Rice SD, Short JW, Stickle WB. 1989. Uptake and catabolism of tributyltin by blue crabs fed TBT contaminated prey. Mar Environ Res 27:137-145.
Richardson ME, Fox MRS, Bry BE, Jr. 1974. Pathological changes produced in Japanese quail by ingestion of cadmium. J Nutr 104:323-338.
Roberson RH, Schaible PJ. 1960. The tolerance of growing chicks for high levels of different forms of zinc. Poult Sci 39:893-895.
Rule JH, Alden RW. 1996. Interactions of Cd and Cu in anaerobic estuarine sediments. II. Bioavailability, body burdens and respiration effects as related to geochemical partitioning. Environ Toxicol Chem 15(4):466-471.

Sample BE, Opresko DM, Suter GW. 1996. Toxicological benchmarks for wildlife. 1996 revision. ES/ERM-86/R3. Office of Environmental Management, US Department of Energy, Washington, DC.
Sanborn HR, Malins DC. 1977. Toxicity and metabolism of naphthalene: a study with marine larval invertebrates. Proc Soc Exper Biol Med 154:151-155.
Schimmel SC, Patrick Jr JM, Forester J. 1976. Heptachlor: toxicity to and uptake by several estuarine organisms. J Toxicol Environ Health 1:955-965.
Schimmel SC, Patrick Jr JM, Wilson Jr AJ. 1977a. Acute toxicity to and bioconcentration of endosulfan by estuarine animals. In: Mayer FL, Hamelink JL, eds, Aquatic toxicology and hazard evaluation, ASTM STP 634. American Society for Testing and Materials, Philadelphia, PA, pp 241-252.
Schimmel SC, Patrick Jr JM, Forester J. 1977b. Toxicity and bioconcentration of BHC and lindane in selected estuarine animals. Arch Environ Contam Toxicol 6:355-363.
Schlicker SA, Cox DH. 1968. Maternal dietary zinc, and development and zinc, iron, and copper content of the rat fetus. J Nutr 95:287-294.
Schroeder HA, Balassa JJ. 1967. Arsenic, germanium, tin and vanadium in mice: effects on growth, survival and tissue levels. J Nutr 92:245-252.
Schroeder HA, Mitchener M. 1971. Toxic effects of trace elements on the reproduction of mice and rats. Arch Environ Health 23:102-106.
Schuytema GS, Krawczyk DF, Griffis WL, Nebeker AV, Robideaux ML. 1990. Hexachlorobenzene uptake by fathead minnows and macroinvertebrates in recirculating sediment/water systems. Arch Environ Contam Toxicol 19:1-9.
Schwetz BA, Norris JM, Kociba RJ, Keeler PA, Cornier RF, Gehring PJ. 1974. Reproduction study in Japanese quail fed hexachlorobutadiene for 90 days. Toxicol Appl Pharmacol 30:255-265.
Shimasaki Y, Kitano T, Oshima Y, Inoue S, Imada N, Honjo T. 2003. Tributyltin causes masculinization in fish. Environ Toxicol Chem 22(1):141-144.
Shopp GM, White Jr KL, Holsapple MP, Barnes DW, Duke SD, Anderson AC, Condie Jr LW, Hayes JR, Borzelleca JF. 1984. Naphthalene toxicity in CD-1 mice: general toxicology and immunotoxicology. Fund Appl Toxicol 4:407-419.
Shubat PJ, Curtis LR. 1986. Ration and toxicant preexposure influence dieldrin accumulation by rainbow trout (*Salmo gairdneri*). Environ Toxicol Chem 5:69-77.
Smith MS. 1969. Responses of chicks to dietary supplements of copper sulphate. Brit Poult Sci 10:97-108.
Spalding MG, Frederick PC, McGill HC, Bouton SN, McDowell LR. 2000. Methylmercury accumulation in tissues and its effects on growth and appetite in captive great egrets. J Wildl Dis 36(3):411-422.
Srinivasan K, Mahadevappa KL, Radhakrishnamurty R. 1991. Toxicity of beta-and gamma-hexachlorocyclohexane in rats of different ages. Bull Environ Contam Toxicol 47:623-627.

Stanley TR, Jr, Spann JW, Smith GJ, Rosscoe R. 1994. Main and interactive effects of arsenic and selenium on mallard reproduction and duckling growth and survival. Arch Environ Contam Toxicol 26:441-451.

Storer RW. 1952. A comparison of variation, behaviour and evolution in the seabird genera *Uria* and *Cepphus*. U Calif Publ Zool 52:121-222.

Takeda H, Shimma Y. 1977. Effects of toxic amounts of dietary zinc on the growth and body components of rainbow trout at two levels of calcium. Bull Freshw Fish Res 27:103-109.

Treon JF, Cleveland FP. 1955. Toxicity of certain chlorinated hydrocarbon insecticides for laboratory animals, with special reference to aldrin and dieldrin. Agric Food Chem 3:402-408.

Treon JF, Cleveland FP, Cappel J. 1955. Toxicity of endrin for laboratory animals. Agric Food Chem 3:842-848.

Tyl RW, Price CJ, Marr MC, Kimmel CA. 1988. Developmental toxicity evaluation of dietary di(2-ethylhexyl) phthalate in Fischer 344 rats and CD-1 mice. Fund Appl Toxicol 10:395-412.

Tyl RW, Myers CB, Marr MC, Fail PA, Seely JC, Brine DR, Barter RA, Butala JH. 2004. Reproductive toxicity evaluationof dietary butyl benzyl phthalate (BBP) in rats. Reprod Toxicol 18:241-264.

USEPA. 1993. Wildlife exposure factors handbook. EPA/600/R-93/187a. Office of Research and Development, US Environmental Protection Agency, Washington, DC.

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Tox Sci 93(2):223-241.

Van Velsen FL, Danse LHJC, van Leeuwen FXR, Dormans JAMA, van Logten MJ. 1986. The subchronic oral toxicity of the beta-isomer of hexachlorocyclohexane in rats. Fund Appl Toxicol 6:697-712.

Vernberg WB, DeCoursey PJ, Kelly M, Johns DM. 1977. Effects of sublethal concentrations of cadmium on adult *Palaemonetes pugio* under static and flow-through conditions. Bull Environ Contam Toxicol 17(1):16-24.

Verschuuren HG, Kroes R, Den Tonkelaar EM, Berkvens JM, Helleman PW, Rauws AG, Schuller PL, Van Esch GJ. 1976. Toxicity of methylmercury chloride in rats. II. Reproduction study. Toxicology 6:97-106.

Vos JG, van der Maas HL, Musch A, Ram E. 1971. Toxicity of hexachlorobenzene in Japanese quail with special reference to porphyria, liver damage, reproduction, and tissue residues. Toxicol Appl Pharmacol 18:944-957.

Walsh AR, O'Halloran J, Gower AM. 1994. Some effects of elevated levels of chromium (III) in sediments to the mullet *Chelon labrosus* (R). Ecotoxicol Environ Saf 27:168-176.

Ware GW, Good EE. 1967. Effects of insecticides on reproduction in the laboratory mouse. II. Mirex, telodrin, and DDT. Toxicol Appl Pharmacol 10:54-61.

Webber HM, Haines TA. 2003. Mercury effects on predator avoidance behavior of a forage fish, golden shiner (*Notemigonus crysoleucas*). Environ Toxicol Chem 22(7):1556-1561.

Windward. 2004. Lower Duwamish Waterway remedial investigation. Quality assurance project plan: Fish and crab tissue collection and chemical analyses. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2007a. Lower Duwamish Waterway remedial investigation. Baseline ecological risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2007b. Lower Duwamish Waterway remedial investigation. Baseline human health risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Wine RN, Li LH, Barnes LH, Gulati DK, Chapin RE. 1997. Reproductive toxicity of di-n-butylphthalate in a continuous breeding protocol in Sprague-Dawley rats. Environ Health Perspect 105:101-107.

Wofford HW, Wilsey CD, Neff GS, Giam CS, Neff JM. 1981. Bioaccumulation and metabolism of phthalate esters by oysters, brown shrimp, and sheepshead minnows. Ecotoxicol Environ Saf 5:202-210.

You L, Casanova M, Bartolucci EJ, Fryczynski MW, Dorman DC, Everitt JI, Gaido KW, Ross SM, Heck HD. 2002. Combined effects of dietary phytoestrogen and synthetic endocrine-active compound on reproductive development in Sprague-Dawley rats: genistein and methoxychlor. Toxicol Sci 66:91-104.